THE VALIDITY AND RELIABILITY OF THE PAVS AND IPAQ-SF AS PHYSICAL ACTIVITY ASSESSMENT TOOLS IN PATIENTS WITH OBSTRUCTIVE SLEEP APNEA

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Efforts to encourage the medical community to prescribe exercise for disease prevention and management have increased significantly in recent years. In patients with obstructive sleep apnea (OSA), it is encouraging that exercise has been shown to improve sleep efficiency, daytime sleepiness, and disease severity. However, in order to better understand the dose-response relationship between exercise and OSA-related outcomes, accurate and reliable methods for assessing physical activity habits are needed. Purpose: To determine the test-retest reliability and validity of two self-report physical activity questionnaires [Physical Activity Vital Sign (PAVS); International Physical Activity Questionnaire-Short Form (IPAQ-SF)] in an OSA population. Methods: 39 adults with moderate-to-severe OSA wore an accelerometer for seven consecutive days and completed the PAVS and IPAQ-SF (twice within 10 d), along with questionnaires on quality of life, sleepiness, and treatment adherence. Test-retest reliability was determined using intraclass correlation coefficients (ICC). Criterion and construct validity were determined using Pearson (r) and Spearman correlation coefficients (ρ), respectively. Results: PAVS and IPAQ-SF scores were reported as total min/wk of moderate-vigorous physical activity (MVPA). Test-retest reliability for MVPA was excellent for PAVS (ICC = 0.982) and good for IPAQ-SF (ICC = 0.766). MVPA assessed via accelerometry was strongly correlated with PAVS (r = 0.802) and moderately with IPAQ-SF (r = 0.569). Both PAVS and IPAQ-SF were significantly correlated with body mass index

(BMI) (ρ = -0.273 and -0.268, respectively), but no other variables. Conclusions: The PAVS and IPAQ-SF are reliable and valid PA questionnaires and may be utilized as a tool for accurately assessing physical activity levels in OSA patients.

Anthony Kaleth, PhD., Chair

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Chapter 1: Introduction to the Study

Introduction

Obstructive sleep apnea (OSA) is a major public health problem characterized by periods of partial or complete upper airway collapse during sleep (Eckert & Malhotra, 2008). The decreased airflow often leads to acute hypoxia and awakening from sleep (Eckert & Malhotra, 2008). These sleep-mediated disruptions in airflow often acutely cause loud snoring, repeated stressful arousals to re-establish breathing, and excessive daytime sleepiness. If left untreated, the long-term consequences of OSA are considerable, complex, and multisystemic.

Regarding long-term consequences, OSA is associated with debilitating effects on daily function and quality of life, including impaired cognitive function, depression, and increased health care use (Punjabi, 2008). Most importantly, however, is the fact that OSA substantially increases risks for major cardiovascular and metabolic disorders, and predisposes individuals to increased mortality (Peppard et al., 2000; Peker et al., 2006; Punjabi & Polotsky, 2006). Although exact costs are difficult to gauge, OSA creates a substantial economic burden, with estimates upwards of $100 billion per year (Knauert et al., 2015).

Early data from the Wisconsin Sleep Cohort Study indicated a relatively low prevalence of OSA (2% to 4%) among middle-aged adults (Skomro & Kryger, 1999). However, over the past two decades, improved techniques for the evaluation of OSA have been developed and clinicians are increasingly aware of the seriousness of this disorder (Peppared et al., 2013). Subsequent research on OSA prevalence now shows

much higher rates among both women (3% to 9%) and men (10% to 17%) (Peppared et al., 2013).

While there are many causes of OSA, one of the greatest risk factors is excess body weight. The relationship between excess body weight and OSA can be seen when examining sleep test data, which has shown that over 60% of patients referred for sleep tests are overweight (Coughlin et al., 2004; Quan et al., 2007; Redline et al., 2003; Young et al., 1993; Strohl & Redline, 1996;). It has become well accepted that there is a direct relationship between excess body weight, physical inactivity, and OSA (Coughlin et al., 2004; Quan et al., 2007; Redline et al., 2003, Tishler et al., 2003; Simpson et al., 2015).

The fact that excess body weight causes OSA is particularly problematic because excess body weight is known to increase the risk for the development of cardiovascular and metabolic disorders, similarly to OSA. Additionally, if OSA is developed due to excess body weight, it is possible that the presence of OSA will further decrease physical activity levels and increase weight gain through daytime sleepiness and cognitive dysfunction, resulting in a vicious cycle which exacerbates the risk of developing or worsening existing OSA, cardiovascular disease, and metabolic disorders (Simpson et al., 2015). Taken as a whole, these facts have made it difficult to understand if the cardiovascular and metabolic disorders seen in OSA patients are a product of obesity, OSA, or a combination of both.

The present protocol for treating OSA consists of using continuous positive airway pressure (CPAP), which applies continuous pressure to keep the airways open during sleep. While CPAP is effective in treating the side effects of OSA, issues exist in its use. The first being that adherence rates remain unacceptably low, ranging between

17% and 85% (Sin et al., 2002; Weaver & Grunstein, 2008; Wolkove et al., 2008; Wozinak et al., 2014). The second and most notable for the interests of this study is that CPAP use does not increase activity levels or decrease body weight, and may even increase body weight (Drager, et al., 2015).

A meta-analysis by Drager and colleagues (2015) examined the influence of CPAP on body weight in those with OSA. They identified 25 separate studies which used CPAP versus controls for a minimum treatment duration of 4 weeks. These studies included a total of 3,181 patients, most of whom were overweight or obese. The analysis concluded that CPAP does not decrease body weight and actually results in increases in BMI with no single predictor for the cause. In this regard, combining recommendations for exercise and physical activity with CPAP may be a viable means to increase daily energy expenditure in patients with OSA, as well as reduce secondary risk factors that place patients at increased risk for worsening of their OSA symptoms and for cardiovascular disease.

Physical activity is known to have many health benefits, including body weight maintenance and reduction, throughout many populations (Miller et al., 1997). Numerous studies have examined the effects of physical activity on OSA patients, most of whom were overweight or obese, and demonstrated that increased physical activity levels result in body weight maintenance or reduction combined with significant reductions in OSA severity (Giebelhaus et al. 2000; Ueno et al., 2009; Kline et al., 2011; Sengul et al., 2011). Importantly, studies have found that increases in physical activity reduce OSA severity even when body weight reductions are not realized (Kline et al., 2011; Sengul et al., 2011). For example, a study by Sengul and colleagues (2011) recruited patients with

moderate OSA and randomized them into exercise and control groups. The exercise group, which performed aerobic exercise three times per week for 1.5 hours per day, saw the number of apnea hypopnea events significantly reduced when compared to the control group. Importantly, this reduction was realized without any reductions in body weight.

The results of the studies examining exercise within OSA patients indicate that interventions to increase physical activity levels would be beneficial for anyone with OSA, but especially for those who are overweight, obese, and/or receiving CPAP treatment. Thus, gauging physical activity levels of OSA patients is important for both researchers and clinicians who aim to understand and, when appropriate, increase physical activity levels of their patients.

Background of the Problem

Many research studies and clinical settings currently gauge OSA patient physical activity levels through self-report questionnaires (Bamberga et al., 2015; Batool Anwar et al., 2014; and Jean et al., 2017; and West et al., 2009). This is a troubling fact because, while many physical activity questionnaires have been proven to be reliable and valid in many healthy and clinical populations, no questionnaire to this date has been validated specifically within an OSA population (Bamberga et al., 2015; Batool Anwar et al., 2014; Jean et al., 2017; and West et al., 2009). The lack of a validated questionnaire makes it difficult to know whether physical activity levels of OSA patients can be accurately assessed through questionnaires.

There are many possibilities as to why validated questionnaires in other populations may not be valid within the OSA population, perhaps the most significant being the presence of daytime sleepiness which is directly related to a lack of

concentration (Zhu et al., 2007). Daytime sleepiness and decreased ability to concentrate may impede OSA patient's ability to answer physical activity questionnaires which commonly rely on their memory from over the course of a week. Some OSA patients, particularly those who are overweight, tend to be sedentary and may have difficulties interpreting questionnaires which ask specific questions about exercise and activity intensities (Igelstrom et al., 2013). Considering these factors, it should not be assumed that a previously validated questionnaire will be valid within the OSA population. This issue can be seen in previous research which has relied on previously validated questionnaires to measure activity levels within the OSA population and produced conflicting results (Basta et al., 2008; Batoll-Anwar et al., 2014; Bamberga et al., 2015; Theorell-Haglow et al., 2011). Considering these facts, the current work aims to determine if there is a questionnaire(s) that can be used as a valid instrument to measure physical activity within the OSA population.

There are two physical activity questionnaires that hold promise in being utilized within the OSA population. The first is a well-established questionnaire called the International Physical Activity Questionnaire Short Form (IPAQ-SF) which can be found in appendix 4 (Marshall et al., 2003). The second is a newer questionnaire in comparison to the IPAQ-SF, called the Physical Activity Vital Sign (PAVS) which can be found in appendix 5 (Ball et al., 2012). The reason the IPAQ-SF and PAVS are promising is because they are both concise and contain questions which are common across the general population (Pereira et al., 1997). These facts are important when considering questionnaires that can be implemented into clinical settings where there is a vast array of patients and limited time.

Significance

Obstructive sleep apnea is a serious health disorder which is becoming more prevalent throughout the population. Currently, a large portion of the OSA population is overweight or obese (Peppared et al., 2013). While being overweight is a primary cause of OSA, OSA may contribute to increases in body weight due to sedentary behavior (Igelstrom et al., 2013). This is a concerning fact because both OSA and excess body weight result in many of the same metabolic and cardiovascular disorders. Equally troubling is that CPAP, the most popular and effective treatment for OSA, has not shown to decrease body weight and may in fact cause it to increase (Drager et al., 2015).

Increasing physical activity levels is a known method for maintaining or reducing body weight and has also been shown to be effective in reducing the severity of OSA, even when body weight reduction is not realized (Sengul et al., 2011; Ueno et al., 2011, Kline et al., 2009). These facts make gauging physical activity levels in all patients with OSA, and especially in those who are overweight or using CPAP, a necessity because having a validated physical activity questionnaire would provide a quick and inexpensive tool for clinicians to accurately determine the amount and patterns of physical activity. It would also allow clinicians to determine how to proceed with appropriate protocols for treatment. Lastly, it could serve as a measure for both physicians and researchers to determine if future protocols aimed at increasing physical activity levels of OSA patients are effective.

Specific Aim 1: To assess the criterion validity of the IPAQ-SF, PAVS, and logbook within an OSA population by comparing their results with an objective measure of accelerometry over the course of one week.

Hypothesis 1. IPAQ-SF, PAVS, and logbook will correlate strongly with one week of accelerometry data from individuals with OSA.

Specific Aim 2: To determine reliability of the IPAQ-SF and PAVS within an OSA population through a test retest design.

Hypothesis 2. IPAQ-SF and PAVS will show strong reliability when taken two times separated by at least one week.

Specific Aim 3: To determine construct validity of the IPAQ-SF, PAVS, and logbook within an OSA population by comparing the results of the questionnaires with BMI, sleepiness, OSA disease severity, CPAP adherence, sedentary time, and quality of life.

Hypothesis 3. Individuals with OSA that have lower levels of physical activity as indicated by the IPAQ-SF and PAVS will have a higher BMI, disease severity, and sleepiness while having a lower sleep quality and CPAP adherence.

Specific Aim 4: To determine the relationship between objective physical activity levels and BMI, sleepiness, OSA disease severity, CPAP adherence, and quality of life.

Hypothesis 4. Individuals with OSA that have lower levels of physical activity as indicated by accelerometry will have a higher BMI, disease severity, and sleepiness while having a lower sleep quality and CPAP adherence.

Methodology

The study design allowed for investigation of the criterion validity, construct validity, and reliability of the IPAQ-SF and PAVS within the OSA population. The study used a descriptive correlation research design. The study consisted of 40 OSA patients between the ages of 18-65 who had been diagnosed with moderate-severe OSA.

Participants were recruited from within central Indiana through word of mouth, flyers, email, and the assistance of Indiana Clinical and Translational Sciences Institute (CTSI). The flyer, email, and CTSI assistance can be found in appendices 1, 2, and 3, respectively. Upon enrollment, participants completed the IPAQ-SF and PAVS questionnaires, and then wore a hip worn accelerometer for seven days for the assessment of physical activity levels. After the seven days were completed, each participant completed the questionnaires again. The study took place over the course of six months which allowed for different beginning dates based on recruitment.

Reliability of the IPAQ-SF and PAVS was determined in a test retest design wherein OSA patients took the questionnaires two separate times at least seven days apart. The results of the two questionnaires were compared to assess whether there was agreement through quantitative analysis. Determining reliability of the IPAQ-SF and PAVS was important because if the results of the questionnaires were not repeatable in the OSA population then they cannot be valid.

Construct validity of the IPAQ-SF and PAVS was assessed through quantitative analysis by examining the consistency between the results of the questionnaires with factors related to OSA, such as BMI, disease severity, CPAP adherence, sleepiness, quality of life, and cognitive impairment. Questionnaires for sleepiness, quality of life, and cognitive impairment can be found in appendices 6, 7, and 8, respectively. Establishing construct validity of the IPAQ-SF and PAVS within the OSA population was important because it helped determine if the questionnaires were accurate in their overall assessment of an OSA patient.

Criterion validity was assessed through quantitative analysis by comparing the results of the IPAQ-SF and PAVS with the objective measure of accelerometry. Determining the criterion validity of the questionnaires within the OSA population was important because if the questionnaires did not measure what they were intended to then they would serve no value.

Delimitations

The study's delimitations include:

1. A power analysis was completed in order to ensure the probability of not committing a Type II statistical error or accepting the null hypothesis when it is in fact false.
2. In order to study a sample of OSA patients who are between the ages of 18-65 and have moderate to severe OSA, participant's electronic medical records were assessed.
3. Participants data from their electronic medical records were collected one week prior to the first visit.
4. The physical activity questionnaires were completed at two time points which were 7 days apart.
5. Questionnaires were completed in person using pencil and paper. The questionnaires were completed privately by the participants.
6. In order to collect 7 days of objective physical activity data, participants wore a hip worn accelerometer for 7 consecutive days.
7. The two questionnaires were put into packets randomly to reduce the potential of survey fatigue.

Assumptions

The study's assumptions include:

1. Participants voluntarily chose to participate in this study out of interest due to the nature of research being conducted.
2. Participants answered the questionnaires truthfully, accurately and to their best ability during each of the two data collection time points.
3. Participants were able to interpret and comprehend what the questionnaires were asking of them.
4. Participants wore the accelerometers truthfully and did not exaggerate sleeping time.
5. The accelerometers accurately measured physical activity levels.
6. Participants did not increase physical activity levels due to the fact they were in a research study studying physical activity levels.

Limitations

The study's limitations include:

1. Due to circumstance, the study was limited to participants who reside in central Indiana. Geographical and cultural differences that exist in other states and countries may influence the results differently.
2. Accelerometers are not 100% accurate in determining physical activity levels.
3. Participants may answer the questionnaires dishonestly to avoid embarrassment or please the researcher.
4. A shortage of empirical data to support the study's hypotheses did not allow for comparison of results to previous studies.

5. OSA patients tend to have many and varying comorbidities which are challenging to account for and may have affected physical activity levels and questionnaire answers.
6. While many questionnaires exist, the study only examined two due to time and the setting of a doctor's office.

Definition of Terms

1. Obstructive sleep apnea (OSA): is a sleep condition which involves the partial or complete blockage of the upper airway during sleep (Eckert & Malhotra, 2008)

2. Physical Activity: bodily movement produced by the contraction of skeletal muscle that significantly raises energy expenditure above basal metabolic level. (American College of Sports Medicine, 2013)

3. Exercise: a type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness. (American College of Sports Medicine, 2013)

4. Questionnaire: a set of questions or other prompts used to obtain information from a respondent about a topic of interest (American Psychological Association, 2015)

5. Reliability: the trustworthiness or consistency of a measure, that is, the degree to which a test or other measurement instrument is free of random error, yielding the same results across multiple applications to the same sample. (American Psychological Association, 2015)

6. Validity: the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of conclusions drawn from some form of assessment. (American Psychological Association, 2015)

Chapter 2: Review of Literature

Introduction

Obstructive sleep apnea (OSA) is a sleep condition which involves the partial or complete blockage of the upper airway during sleep (Eckert & Malhotra, 2008). A partial blockage results in shallow breathing (hypopnea) while a complete blockage results in total cessation of breathing (apnea) (Eckert & Malhotra, 2008). In either case, decreases in oxygen saturation (hypoxia) occur which typically cause arousal from sleep. The severity of OSA is determined by the number of hypoxic episodes per hour, with one episode classified as either apnea lasting 10 seconds and a 3% reduction in oxygen saturation or hypopnea which decreases airflow by 50% and lasts 10 second with a 3% reduction in oxygen saturation (Eckert & Malhotra, 2008). The number of episodes per hour is used to determine the apnea hypopnea index (AHI), with more frequent episodes indicating more severe OSA (Normal: AHI <5, Mild: AHI 5≤ but <15, Moderate: AHI 15≤ but <30, Severe: AHI ≥30). In order for the sleep apnea to be defined as obstructive, thoracoabdominal effort must be present in at least 70 percent of episodes.

Over time, if OSA is left untreated, the severity of OSA typically increases resulting in deleterious effects on health (Dick et al., 2007; Hoffman et al., 2002; Zhu et al. (2007); Peppard et al., 2000). Moderate and severe OSA have numerous negative health effects on the human body including hypertension, insulin resistance, cardiovascular disease, and neurological dysfunction (Dick et al., 2007; Hoffman et al., 2002; Zhu et al. (2007); Peppard et al., 2000). Research has found a direct relationship between excess body weight and OSA and has also demonstrated that the severity of OSA increases with increases in body weight (Peppard et al., 2000). The relationship

between OSA and body weight remains complex as excess body weight is a risk factor for many of the same cardiovascular and metabolic diseases as OSA.

Considering the problematic and complex relationship between OSA and excess body weight as well as the fact that CPAP does not result in body weight reductions, recommendations for increasing exercise and physical activity in OSA patients, especially those who are overweight and or receiving CPAP, may be a viable means to increase daily energy expenditure. Increases in daily energy expenditure would likely assist in reducing the severity of OSA through a combination of poorly understood physiological factors and body weight reductions, both of which would ultimately reduce the risk of developing or worsening metabolic and cardiovascular diseases.

These facts make gauging physical activity levels of those with OSA important. A validated questionnaire would provide patients with a clear picture of their activity levels which may be beneficial in motivating the patients to increase activity levels. It would also be beneficial to clinicians in determining if physical activity recommendations should be made as part of treatment for OSA. Lastly, it could also serve as a measure for both physicians and researchers to determine if future protocols aimed at increasing physical activity levels of OSA patients are effective.

Presently, when physical activity levels are gauged in a clinical setting, questionnaires are typically used, however, no questionnaire to this date has been validated in the OSA population resulting in potentially inaccurate assessment of physical activity levels for this population. This review will present the exiting literature on the etiology, pathophysiology, and related sequelae of OSA. This review will also summarize

the effects of exercise on OSA and lastly describe existing physical activity questionnaires which may be appropriate for use in the OSA population.

Etiology of OSA

Age. Research has shown that with increasing age comes greater difficulty with falling asleep and staying asleep. A study by Foley and colleagues (1995) found that over 50% of individuals older than 65 had sleep related complaints. The prevalence of OSA has been shown to increase with age in both men and women. A study by Bixler and colleagues (1998) found the presence of OSA to be 3.2% for men between the ages of 20-44 years of age and 18.1% for those between the ages of 61-100 years of age. A later study by Bixler and colleagues (2001) found the presence of OSA in women to be 0.6% for those between the ages of 20-44 years of age and 7.0% for those between the age of 61-100 years of age. Some theories as to why OSA prevalence increases with age are increased fat within the area of the pharynx, anatomical changes to structures located around the pharynx, and lengthening of the soft palate (Malhotra et al., 2006).

Body Weight. Excess body weight has been shown to be the strongest risk factor for OSA with over 60% of patients referred for sleep tests being overweight (Strohl & Redline, 1996). Numerous studies have concluded that there is a direct relationship between excess body weight and OSA (Bixler et al., 1998; Bixler et al., 2001). Not only has a relationship between excess body weight and OSA been shown, but an increase in weight over time has been shown to accelerate the severity of OSA (Newman et al., 2005). To further solidify the relationship between excess body weight and OSA, a study by Grunstein and colleagues (2007) found that a reduction in excess body weight in those with OSA resulted in either a decrease in the severity of OSA or complete attenuation of

the disease. Excess body weight is believed to influence OSA through several different mechanisms, including increased fat deposits around the pharynx which narrow the upper airway, decreased airway patency due to altered neural compensatory mechanisms, respiratory instability, and reduced functional residual capacity (Fogel et al., 2004).

Sex. Many studies have confirmed that there is a higher prevalence of OSA in males versus females. The epidemiological studies which have examined OSA in males and females have found between a 2 to 3:1 ratio in favor of males (Bixler et al., 2001; Duran et al., 2001). Besides a greater prevalence of OSA in men than women, polysomnography tests have shown women have less frequent arousals with shorter durations when sleeping, collectively resulting in less severe hypoxia (Ware et al., 2000). Theories as to why differences in OSA exist between men and women are anatomical differences of the upper airway and hormonal differences. The effects of hormones on OSA are best seen in a study by Bixler and colleagues (2001) which found that the prevalence of OSA was higher in post-menopausal women. In the same study by Bixler et al., (2001) it was found that post-menopausal women on hormone replacement therapy were less likely to have OSA.

Race. Studies examining OSA in eastern cultures have found that the prevalence of OSA in Asians is similar to that of North Americans and Europeans. These findings were particularly surprising because despite a lower prevalence of obesity in the east, OSA prevalence was the same (Li et al., 2000). In a follow-up study by Lam and colleagues (2005), who examined the differences between facial anatomy of those in the east and west, it was concluded that differences in facial anatomy are the likely cause of the equal prevalence of OSA in Asians despite significantly lower obesity rates.

Studies examining African Americans have found that those less than 25 years old and those 65 years old and older have a higher prevalence of OSA than other racial groups (Redline et al., 1997). Studies examining Hispanics have found that they are more likely to snore with OSA than other racial groups (O'Connor et al., 1997). The reasoning behind these differences seen in African Americans and Hispanics is poorly understood, but it is possible, particularly in those equal to or older than 65, that the existence of comorbid conditions commonly seen in minority groups contributes to the increased prevalence of OSA (Douglas et al., 2003; Cossrow and Falkner, 2004). More research is needed in understanding health disparities within OSA minority groups.

Facial Anatomy. Differences in facial anatomy have been observed in those with and without OSA which likely influence its development (Lee et al., 2010). The enlargement of the tonsils, tongue, and soft palate, inferiorly located hyoid bone, mandibular and maxillary retroposition, and decreased posterior airway space have all been indicated as anatomical possibilities for the development of OSA. The length of mandible has been shown to have the strongest association with OSA (Lee et al., 2010).

Genetics. In the previous sections, the factors of obesity, race, and facial anatomy were implicated as underlying etiology for OSA. With this in mind, there may be an existing genetic component which is influential in the development of OSA. Numerous studies have indicated this possibility. In a study by Redline and colleagues (1995) it was found that those with first-degree relatives who have OSA were more at risk of developing OSA when compared with those whose first-degree relatives did not have OSA. The study also found that those with a greater number of relatives with OSA had an

increased risk of developing OSA. The Cleveland family study found that the severity of OSA was directly linked to genetic factors (Redline and Tishler, 2010).

Rostral Fluid Shift. The prevalence of OSA has been demonstrated to be higher in patients who have fluid retention, such as patients with heart failure. Due to gravity, it is believed that fluid accumulates in the intravascular and interstitial spaces of the legs throughout the day. Once these patients lay down at night, the fluid redistributes rostrally and ends up in the neck and causes increased pressure and narrowing of the upper airways (White and Bradley, 2013).

Pathophysiology of OSA

Carotid Chemoreceptor sensitivity. Activation of the sympathetic nervous system is elevated in OSA patients when they are both sleeping and awake. This increase in sympathetic activation during sleep is likely due to the chronic intermittent hypoxia (CIH) experienced from OSA (Dick et al., 2007). The CIH during sleep results in activation of the carotid body chemoreceptors via decreases is oxyhemoglobin which results in sympathetic activation (Dick et al., 2007). Aside from sleep, sympathetic activity has also been shown to be elevated in OSA patients during wakefulness which is evidenced by increased discharge rates of carotid chemoreceptors in OSA patients even during normoxia (Peng et al., 2003). The enhanced sympathetic activity during wakefulness indicates that the CIH experienced from OSA sensitizes the carotid chemoreceptors and results in enhanced sympathetic activity while awake and asleep (Dick et al., 2007). Research has pointed to the development of reactive oxygen species from CIH as a potential cause of sensitized carotid chemoreceptors in OSA patients (Dick et al., 2007).

Enhanced sympathetic activity is the likely driver of elevated angiotensin (ANG) II seen in OSA patients. Chronic intermittent hypoxia has been shown to upregulate angiotensin II receptors in the carotid body and lead to enhanced carotid body activity resulting in an elevated sympathetic state (Li et al., 2006). ANG II has also been shown to activate NADPH oxidase which drives the production of reaction oxygen species within cells. These reactive oxygen species have also been demonstrated to cause the sensitization of the carotid chemoreceptors (Li et al., 2007). In conclusion, ANG II likely sensitizes the carotid chemoreceptors through due to upregulation of angiotensin II receptors from CIH. Angiotensin II may also sensitize the carotid body chemoreceptors through activating NADPH oxidase which results in oxidative stress to the chemoreceptors (Li et al., 2006; Li et al., 2007).

Decreased Baroreflex Control. Research has indicated that OSA patients have decreased baroreflex control when compared to healthy patients. (Carlson et al., 1996). This is important when considering OSA patients have elevated sympathetic activity due to sensitized carotid chemoreceptors which results in elevated blood pressure. A desensitized baroreflex results in an inability to activate the parasympathetic nervous system and consequently further exacerbates the effects of an already elevated sympathetic nervous system (Carlson et al., 1996).

Research has indicated that carotid chemoreceptors becoming sensitized most likely comes prior to the desensitized baroreceptors. In a study examining CIH in rats, arterial blood pressure increased prior to the baroreceptors becoming desensitized (Li et al., 2006). If this holds true in humans is not fully understood, but nonetheless, a

combination of sensitized carotid chemoreceptors and desensitized baroreceptors results in a hyperactive sympathetic environment.

Central Sympathetic. Nitric oxide (NO) is an inhibitor of carotid body chemosensitivity as demonstrated by research in rabbits which has shown inhibition of NO results in increased carotid chemoreceptor sensitivity (Sun et al., 1999). Research in rats has demonstrated that CIH results in downregulation of NO in carotid chemoreceptors most likely due to increased ANG II which has a strong inhibitory effect on NO (Marcus et al., 2010). In conclusion, downregulation of NO from CIH may be responsible for increases in carotid chemoreceptor sensitivity.

CIH has been suggested to increase central sympathetic output by way of ANG II. Sympathetic neurons in the brain stem receive input from higher centers such as the paraventricular nucleus (PVN) of the hypothalamus (Dampney et al., 2005). ANG II is a known inhibitor of NO in the central nervous system where it serves to regulate central sympathetic outflow (Liu et al., 1998). CIH exposure decreases NO expression in the PVN and increases angiotensin receptor expression indicating CIH may increase central sympathetic output (Liu et al., 1998). Consequently, hypoxia in OSA patients may increase ANG II and decrease NO which may lead to the increased sympathetic state commonly seen in OSA patients.

Sympathetic State and Insulin Sensitivity. It is well established that OSA patients have elevated levels of catecholamines (Minemura et al., 1998). These elevated levels of catecholamines in OSA patients may have an influence over insulin resistance. Besides countering the action of insulin, catecholamines also inhibit the release of insulin from the pancreases (Hoffman et al., 2002). Growth hormone has been demonstrated to

be reduced in OSA patients, which may also play a role in insulin resistance because a lack of growth hormone results in a decrease of insulin-like growth factor I (IGF-I), which has insulin-sensitizing actions (Gianotti et al., 2002).

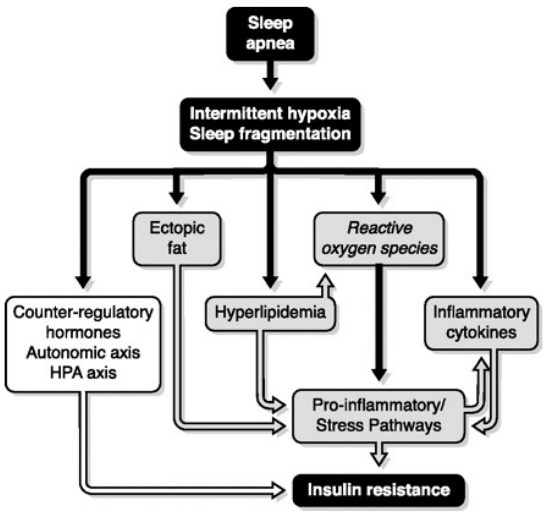
Evidence for OSA and insulin resistance has also been demonstrated in rats. In a study examining rats who were exposed to CIH, sensitization of the hypothalamic-pituitary-adrenal (HPA) axis was observed, and consequently levels of corticosterone were elevated. Importantly, elevated levels of corticosterone was positively correlated with levels of blood sugar signaling a potential driver of insulin resistance (Ma et al., 2008).

Inflammation and Insulin Sensitivity. In obese subjects, numerous factors have been suggested to create a pro-inflammatory environment, including the production of reactive oxygen species and inflammatory cytokines (Yuan et al., 2001). Both reactive oxygen species and inflammatory cytokines have shown associations with insulin resistance. These same pathways which induce inflammation have been demonstrated to become active under CIH seen in OSA patients (Dyugovskaya et al., 2002). Intuitively, consistent states of hypoxia have the potential to drive the generation of reactive oxygen species within cells, and as discussed in previous sections, the ANG II NADPH oxidase pathway seen in OSA patients is also involved in their production.

Chronic Intermittent hypoxia may also drive the production of pro-inflammatory cytokines which have been directly implicated in insulin resistance. Two important inflammatory cytokines known to be involved with insulin resistance in obese patients are tumor necrosis factor alpha (TNF-α) and interleukin 6 (IL-6). Both TNF-α and IL-6

have been shown to increase from CIH (Minoguchi et al., 2004). See figure 1 for a depiction of the sleep apnea insulin resistance pathway.

Figure 1. Sleep Apnea Pathophysiology



Neural Injury. It is well established that OSA leads to cognitive impairments. Studies in mice have shown that CIH results in irreversible decreases in sleep latency and reductions in total wake time (Veasey et al., 2004). Similar to the effects seen in humans, Zhu and colleagues (2007) have shown that the neurons involved in wakefulness are injured by CIH. The injured neurons observed in the study by Zhu et al. (2007) were catecholaminergic and showed increased oxidative injury in response to the CIH. The increased oxidative injury is likely caused by NADPH oxidase which is found within the neurons. Thus, the elevated sympathetic state in OSA may play an important role in damaging wake neurons by inducing oxidative stress.

Svanborg (2005) demonstrated through electromyography that OSA patients have impaired sensory and motor nerve function of the palatopharyngeus muscle. This finding is supported by the fact treatment of OSA partially reverses the deficits seen in the motor

and sensory nerves (Svanborg, 2005). Histological studies have shown motor neurons of the palatopharyngeus muscle to be demyelinated in OSA patients (Boyd et al., 2004). The severity of peripheral nerve dysfunction correlates with oxyhemoglobin desaturations in sleep apnea.

Sequalae of OSA

Hypertension. Many studies have identified associations and direct relationships between hypertension and OSA (Peppard et al., 2000). In the Wisconsin Sleep Study, there was a linear relationship between OSA severity and hypertension (Peppard et al., 2000). Animal studies have demonstrated exposure to intermittent hypoxia produces elevations in blood pressure during both the period of exposure and afterwards in normoxic conditions (Brooks et al., 1997). Other evidence pointing towards a relationship between OSA and hypertension is seen in CPAP studies. Studies examining CPAP use in OSA patients have shown reductions in daytime blood pressure and in 24-h mean blood pressure (Becker et al., 2003).

Stroke

Stroke. An association between OSA and stroke has been observed in numerous studies (Arzt et al., 2005; Wessendorf et al., 2000). Arzt and colleagues (2005) found that moderate to severe OSA was associated with increased risk of stroke, compared to mild OSA which did not increase stroke risk. Munoz and colleagues (2006) found that stroke was three times more likely in subjects with AHI values greater than 30 compared to those with values less than 30. The study also found that patients with coronary artery disease and OSA (AHI >10) were more likely to have a stroke when compared to those without OSA (Munoz et al., 2006). A large clinical study examined the effects of OSA on

all-cause mortality in patients with preexisting stroke and found that those with OSA hypoxia hypopnea index values of greater than 30 were at a higher risk of death from any cause than in those with values below 15 (Sahlin et al., 2008).

Coronary Artery Disease. Numerous studies have shown relationships between OSA and coronary artery disease (Mooe et al., 1996; Sorajja et al., 2008). These studies found OSA to be of equal significance to diabetes, hypertension, and obesity when predicting the likeness of coronary artery disease. When coronary artery calcification was determined by computed tomography, a positive relationship was found between OSA severity and level of calcification (Sorajja et al., 2008). It is also possible that OSA may influence morbidity and mortality in patients with existing coronary disease. Since OSA often causes chest pains and ischemia, OSA may increase the incidence of heart attacks in those with existing coronary artery disease.

Diabetes. The Nurses' Health Study followed 69,852 women without diagnosed diabetes finding 1,957 developed diabetes over a 10 year period. The study found that those who snored were two times more likely to develop diabetes than those who did not (Al-Delaimy et al., 2002). Other studies have used polysomnography to measure OSA more objectively and have found the presence of severe OSA to be positively associated with diabetes as determined by fasting insulin and glucose (Lp et al., 2002). These studies came to their conclusions independent of obesity. Similar findings were seen in a study by Punjabi et al. (2002) who analyzed subjects with mild to moderate OSA and found increased fasting and 2-h glucose levels as determined glucose tolerance tests. One of the largest studies to examine OSA and obesity by Punjabi et al. (2004) directly assessed 2,656 subjects from the ongoing Sleep-Heart-Health study. They found that subjects with

AHI values of 15 or greater had increased insulin resistance values as determined by The Homeostasis Model Assessment. They also found elevated fasting glucose levels and elevated two hour glucose levels, as determined by glucose tolerance tests. The findings of this study were still significant after adjustment for age, BMI, waist girth, race, sex, and smoking.

Daytime sleepiness. Two-thirds of adults with OSA complain of significant sleepiness and fatigue (Chervin et al., 2002). The value which has been shown to most strongly predict sleepiness from OSA is the desaturation index (Bedard et al., 1993). While treatment of OSA with CPAP has shown improvement in subjective sleepiness, clinical trials have found that when sleepiness is examined objectively through sleep latency there is no significant improvement from CPAP treatment. These studies have found less than a 1-minute improvement in sleep latency from CPAP treatment (Patel et al., 2003).

Cognitive Performance. OSA has been shown to impair cognitive function. As an example, Thomas and colleagues (2005) examined OSA patients' cognitive function via functional MRI in 21 to 50-year old subjects. The OSA patients had less activation of the prefrontal cortex while performing a working memory task. A similar observation was made in hypoxic and nonhypoxic subjects with sleep apnea, suggesting that hypoxia does not influence the decrement in prefrontal cortical activation during learning. In contrast, hypoxic subjects showed far less activation in the parietal cortex. This suggests that within the brain there are regional differences for hypoxia-sensitive neural tissue and arousal or sleep disruption-sensitive neuronal tissue.

One of the more alarming findings from recent studies is that young children with sleep apnea may also have neuronal loss and cognitive impairments. Halbower et al. (2006) examined 19 children with sleep apnea and 12 controls, matched for age, gender, ethnicity, and socioeconomic class. Children with severe sleep apnea had significant decrements in their IQ (15 points) and significant decrements in verbal working memory and verbal fluency.

Challenges to Diagnosis and Treatment

Diagnosis. Presently some research estimates that over 85% of patients with moderate to severe OSA are undiagnosed (Kato et al., 2009). One of the most important issues surrounding this is believed to be that patients with OSA are unaware of the snoring and repetitive episodes of arousal during the night (Victor, 1999). If left unware of these issues, OSA will commonly present itself to both the patients and clinician as unrelated health disorders. This is due to the fact OSA has many comorbidities and sequelae, as previously discussed, which can present similar symptoms.

Even when OSA is suspected, diagnostic issues persist. Polysomnography is a multiparametric test which is run during a night of sleep. The test examines brain, eye, muscle, and heart activity along with respiratory effort and arterial oxygen saturation. While polysomnography lab tests are effective in diagnosing OSA, they are not widely available and typically cost thousands of dollars. While insurance companies will typically cover the cost of a sleep study, the United States Census Bureau estimates that there are currently 28.1 million uninsured Americans and that number is estimated to rise in the coming years (USCB, 2018). This is particularly troubling for OSA in that minority

groups such as Hispanics and African Americans are more often uninsured and have higher rates of OSA than whites (Redline et al., 1997; O'Connor et al., 1997.).

Treatment. When OSA is diagnosed, the standard of care for the great majority of patients is CPAP. When used effectively, CPAP has been shown to improve daytime drowsiness, physical functioning, vitality, mood, and attenuate OSA-related hypertension, an important cardiovascular disease (CVD) risk factor (Bazzano et al., 2007; Fatureto-Borges et al., 2016; Liu et al., 2016; Lewis et al., 2017; Zaho et al., 2017). Unfortunately, adherence rates remain unacceptably low, ranging between 17% and 85% (Sin et al., 2002; Weaver & Grunstein, 2008; Wolkove et al., 2008; Wozinak et al., 2014). Even in patients reporting "good adherence", CPAP has not been shown to promote weight loss and may even cause weight gain (Drager et al., 2015).

Weight Gain and Health

CPAP and Weight Gain. A meta-analysis by Drager and colleagues (2015) looked at the influence of CPAP on body weight in those with OSA. They identified 25 separate studies which used CPAP versus controls for a minimum treatment duration of 4 weeks. These studies included a total of 3,181 patients, most of whom were overweight or obese. The analysis concluded that CPAP use results in significant increases in body weight with no single predictor for the cause. This is problematic due to the fact excess body weight causes OSA and increases in body weight increase the severity of OSA while driving many of the same metabolic disorders which OSA causes such as hypertension, heart disease, and diabetes.

Hypertension. Hypertension has been linked to excess body weight in many studies (Black, 2003). Hypertension occurs when blood vessels have an increased

resistance to blood flow (Black, 2003). Elevated blood pressure naturally occurs during times of arousal to move larger quantities of blood to desired organs, however, during a resting state, blood pressure should not be elevated as seen in a large majority of the obese population (Bassett, 2008). Many cardiovascular complications have been shown to arise from hypertension such as left ventricular hypertrophy, atrial and ventricular arrhythmias, diastolic heart failure, systolic heart failure, and most commonly ischemic heart disease with or without congestive heart failure. (Black 2003).

Possible mechanism underlying the development of hypertension in obese individuals are altered angiotensin II and aldosterone secretion (Zorad, 1995). Obesity has also been shown to cause structural changes to the kidneys which interfere with and eventually cause the total loss of nephron function resulting in hypertension (Hall 2003). Ectopic fat deposits on the kidneys measured by CT have also been shown to be predictive of hypertension (Tchernof and Després, 2013). Consequently, while OSA may cause hypertension, weight gain from OSA may exacerbate the issue by increasing angiotensin II and aldosterone secretion.

Atherosclerosis. Ischemic heart disease or atherosclerosis arises from the dyslipidemic state frequently observed in obese individuals (Tchernof and Després, 1996). Atherosclerosis occurs when an artery wall thickens due to the accumulation of atheromas, which form due to the invasion of triglycerides, cholesterol, and white blood cells (Lang et al. 2011). The development of atherosclerosis can be influenced by a variety of factors such as obesity, genetics, dietary choices, and the environment (Lang et al. 2011). While there are many possibilities and theories for how these factors initiate

atherosclerotic development, most scientific literature points towards being overweight and or obese, as one of the primary driving factors (Tchernof and Després, 2013).

Over time continued development of atheromas lead to stenosis or narrowing of the lumen (Austin, 1988). The normally thin tunica intima becomes the thickest layer of the vessel with large lighter colored atheroma's within. This narrowing leads to increased pressure within the arteries and eventual ruptures of atheroma's. A rupture of an atheroma causes blood clotting and obstruction of blood flow which typically results in a myocardial infarction or heart attack (Austin, 1988). If the heart attack is not fatal the rupture is then covered by a fibrous organization which results in greater stenosis. The increased stenosis further increases pressure within the arteries which increases the chance of another atheroma rupture and consequent heart attack (Pascot et al., 2001). Consequently, while OSA may cause heart disease, weight gain from OSA may exacerbate the issue by increasing the development of atheromas within coronary arteries.

Type 2 Diabetes Lots of evidence exists for the association between excess body weight and insulin resistance which ultimately leads to the development of type II diabetes (Karter, 2005). Insulin resistance occurs when insulin can longer bind to its tyrosine kinase receptor, consequently resulting in a lack of glucose transporter 4 (GLUT4) translocation to the cell membrane which is what normally allows glucose into the cell (Karter, 2005). This results in abnormally high levels of not only glucose, but also insulin, which over time can lead to kidney failure, acidosis, and death if not treated (Karter, 2005).

Excess body weight may contribute to the development of diabetes through the release of cytokines such as TNF-α and IL-6 by adipocytes. The release of these

cytokines results in a systemic inflammatory state, disrupting insulin receptor function, causing insulin resistance (Tchernof and Després, 2013). Excess body weight has also been shown to be strongly associated with elevated levels of free fatty acids in circulation. This likely occurs under the influence of inflammatory cytokines which have been shown to be elevated in overweight individuals, as discussed prior (Tchernof and Després, 2013). The overexposure of free fatty acids may impair liver metabolism leading to the overproduction of apolipoprotein B-containing lipoproteins, increased hepatic glucose production, and reduced hepatic degradation of insulin, which exacerbates systemic hyperinsulinemia (Tchernof and Després, 2013). Consequently, while OSA may cause diabetes weight gain from OSA may exacerbate the issue by increasing the release of TNF-α and IL-6 by adipocytes.

Exercise, Body Weight, and OSA

Exercise. Increased physical activity levels have long been known to decrease excess body weight and reduce or attenuate related metabolic disorders such as hypertension, diabetes, and atherosclerosis. Considering the strong and complicated relationship between OSA, obesity, and the metabolic disorders which are commonly seen in both, increased physical activity levels in OSA patients may have the potential to provide many benefits. The existing research on the effects of exercise in OSA patients has proven promising.

Epidemiological Studies. Some initial compelling evidence for the study of nutritional and physical activity interventions in OSA patients was seen in a large longitudinal study by Peppard et al. (2000) in which 690 Wisconsin residents were evaluated twice over 4 years for disordered breathing. The study found that those who

increased their weight by 10% over the course of 4 years significantly increased the number of apnea hypopnea events per night. Importantly, the study also found that those who decreased their weight by 10% significantly decreased the number of apnea hypopnea events per night. The reasons for the weight varied among participants but included bariatric surgery, exercise, and diet. The evidence from this study clearly demonstrates a relationship between weight gain and an increased risk for the development and severity of OSA, while weight loss is related to a reduced severity of OSA.

Another large longitudinal epidemiological study supporting the importance of weight and OSA was by Newman and colleagues (2005) which was designed to examine the impact of disordered breathing on cardiovascular disease risk. The study analyzed 2968 men and women via polysomnography over the course of 5 years. The study found that increased weight over time increased the risk of disordered breathing development and severity and that decreased weight over time decreased the severity of disordered breathing.

Experimental Studies. One of the earliest studies to directly focus on employing physical exercise interventions as a modality for improving OSA was by Giebelhaus et al. (2000), in which 11 adult participants with moderate to severe OSA were recruited. All participants completed two hours of exercise twice per week for 6 months, with one session being aerobic exercise and the other being resistance training. Before and after the 6-month intervention, polysomnography was utilized to determine sleep quality. Following the study, a significant decrease in the number of apnea hypopnea episodes

were seen (32.8 to 23.6). Interestingly, despite an improvement in objective sleep quality, no decreases in body weight were found.

A study by Ueno and colleagues (2009) recruited 17 severe sleep apnea patients with heart failure. Of the participants, eight had obstructive sleep apnea (OSA) and nine had central sleep apnea (CSA). All participants completed a 4-month exercise program which consisted of 60 minutes of aerobic exercise three times per week. Before and after the 4-month period, polysomnography was used to determine the severity of OSA. The study found exercise training decreased the number of apnea-hypopnea events per hour, improved oxygen saturation, improved subjective quality of life, and decreased muscular sympathetic nerve activity in patients with OSA but not CSA.

A more recent randomized control trial by Kline and colleagues (2011) recruited 43 sedentary and obese adults with moderate to severe OSA. The participants were randomly chosen to be in an exercise training group or stretching group. The exercise training group met four times per week for 12 weeks and performed a total of 150 minutes of moderate intensity aerobic exercise per week. The exercise training group also performed resistance training following aerobic training two days per week. The participants in the stretching group met twice per week for 12 weeks to perform whole-body flexibility exercises.

OSA severity was determined by overnight polysomnography before and after the 12-week interventions. The study found that exercise training resulted in a significant decrease in the number of apnea hypopnea episodes (32.2 ± 5.6 to 24.6 ± 4.4) per night and consequent improvements oxygen saturation as well as improvements in subjective sleep quality. No significant changes were seen in any variables in the stretching group.

Interestingly, reductions in OSA were not seen with simultaneous reductions in body weight; however, significant improvement in body composition were seen.

A similar randomized control trial study by Sengul and colleagues (2011) recruited 20 patients with mild to moderate OSA. The participants were randomized into either an exercise or control group. The exercise group performed aerobic exercise three days per week for 12 weeks, with the exercise lasting 1.5 hours per day. The severity of OSA was analyzed via polysomnography before and after the 12-week intervention in both groups. Following the intervention, the exercise group demonstrated significant decreases in the number of apnea hypopnea events per night while significantly increasing subjective sleep scores. The control group saw no significant changes from pre to post intervention. Similar to the study by Kline and colleagues (2011), the experiment showed improvements in OSA without decreases in body weight or body composition.

In conclusion, the discussed experimental studies demonstrate that exercise in OSA patients improves neurovascular function, subjective sleep quality, and objective sleep quality. These effects occurred independent of decreases in body weight.

Mechanisms and Implications of Apnea Hypopnea Episodes. The mechanisms by which exercise decreases the number apnea hypopnea episodes per night is not fully understood but a variety of different theories have been proposed. One possibility is that exercise training reduces fluid accumulation in the neck, increasing the diameter of the upper airways and preventing collapse (Shiota et al., 2007). In the study discussed previously by Ueno et al. (2009), it was found that exercise training increased left ventricular ejection fraction in subjects with OSA, indicating the possibility that improved cardiac function may reduce edema in the upper airways and improve OSA.

Mechanisms and Implications of Hypertension and Cardiovascular Disease.

Another possibility is that reduced sympathetic nerve activity from exercise training may improve OSA. It is well established and accepted that OSA leads to enhanced sympathetic activity which is associated with increased cardiovascular disease risk. The mechanism by which OSA increases sympathetic activity is likely through two pathways. The first and acute pathway being that an increased hypoxic state in OSA stimulates carotid body chemoreceptors during sleep which activate sympathetic nerve activity. The second and long-term pathway is through increased angiotensin II which directly stimulates the carotid body chemoreceptor and sensitizes it. This sensitization likely occurs by direct influence of angiotensin II or through activation of NADPH oxidase and increased reactive oxygen species. In either case, angiotensin II sensitizes the carotid chemoreceptor and causes a sustained increase in sympathetic nerve activity seen during arousal.

The previously discussed study by Ueno and colleagues (2009) found that exercise training suppressed sympathetic nerve activity. This suppression may have been from decreased angiotensin II and increased nitric oxide which has been previously demonstrated in exercise research. Nitric oxide has been shown to play an inhibitory role in the carotid body chemoreceptor in keeping it desensitized. Besides angiotensin II directly sensitizing the carotid body chemoreceptor, it also does so indirectly by decreasing nitric oxide levels. Thus, by decreasing angiotensin II and increasing nitric oxide, it is possible that exercise desensitizes the carotid body chemoreceptor and consequently decreases sympathetic nerve activity. A decreased sympathetic state while sleeping may decrease the frequency of arousal and improve symptoms of OSA patients.

Independent of the exact mechanism, it is clear exercise training decreases sympathetic nerve activity in OSA patients which is of significant benefit due to the relationship of OSA and cardiovascular disease. Overwhelming evidence suggests OSA causes the development or worsens cardiovascular disease in the form of atherosclerosis, hypertension, and stroke (Punjabi et al., 2008). Much of the OSA cardiovascular sequalae is a product of increased sympathetic activity. Thus, exercise decreasing sympathetic nerve activity may have profound influence over decreasing cardiovascular disease risk in OSA patients.

Further Considerations. Numerous studies have demonstrated that exercise training in obese participants results in decreased inflammatory cytokines. These findings are significant in that previous research has demonstrated a strong relationship between inflammatory cytokines and the development of insulin resistance. Interestingly, elevated levels of inflammatory cytokines and insulin resistance have been seen in OSA patients suggesting that OSA may cause their production independent of obesity.

Besides inflammatory cytokines, the production of reactive oxygen species is also believed to be involved in the inflammatory process which drives insulin resistance (Yuan et al., 2001). As discussed previously, reactive oxygen species have been shown to be elevated in OSA patients likely due to the intermittent hypoxic states and angiotensin II/ NADPH oxidase pathway. Future research should examine if exercise training specifically in OSA patients influences inflammatory cytokines, angiotensin II, and reactive oxygen species.

While the consequences of untreated OSA are significant, research has provided insight into possible modalities which look promising in decreasing the severity or

entirely attenuating OSA. One modality which looks particularly promising is that of physical activity which has shown to decrease the number of apnea hypopnea events per night, decrease sympathetic nerve activity, increase subjective sleep quality, and improve overall quality of life. Future research may expand on specific mechanisms by which exercise improves OSA, as well as exercise implications in specific diseases related to OSA such as cardiovascular disease and diabetes.

Physical Activity Questionnaires

It is well established that physical activity has positive effects on many aspects of health (Piercy et al., 2018). Despite this understanding, many challenges exist in gauging the physical activity levels and general fitness of patients within clinical settings. Most traditional forms of physical activity assessment are very involved, time consuming, and consequently impractical within the healthcare setting where healthcare providers already have little time (Smith et al., 2005; Glasgow et al., 2005). This is why any tool used to measure physical activity levels within the healthcare setting must be quick and efficient.

Considering the impracticality of objective measures for physical activity measurement within clinical settings, physical activity levels most often are measured subjectively through questionnaires. Most questionnaires utilized within clinical settings ask questions regarding the frequency and type of physical activity performed during the previous seven days. The frequency and type of activity are then added to measure total activity over the course of a typical week. This can be difficult for many patients to report, especially more sedentary patients who are unfamiliar with physical activity intensities.

Unsurprisingly, physical activity questionnaires are currently used to gauge activity levels of OSA patients in clinical settings and in clinical research (Basta et al., 2008; Batoll-Anwar et al., 2014; Bamberga et al., 2015; Theorell-Haglow et al., 2011). This may be problematic due to the fact OSA patients tend to have increased levels of sleepiness which decrease the ability to concentrate which may decrease the accuracy of the questionnaires (Lindberg and Gislason, 2000). Considering these factors, it should not be assumed that a previously validated questionnaire will be valid within the OSA population. This issue can be seen in previous research which has relied on previously validated questionnaires to measure activity levels within the OSA population (Basta et al., 2008; Batoll-Anwar et al., 2014; Bamberga et al., 2015; Theorell-Haglow et al., 2011).

A study by Batool-Anwar and colleagues (2014) examined the influenced of CPAP on physical activity patterns. In order to accomplish this, they recruited 231 participants with moderate to severe OSA and randomly assigned them to either a CPAP group which utilized CPAP or a CPAP sham group which believed they were utilizing CPAP but were not. Participation lasted four months and activity levels via questionnaire were taken before and after. The study found that those who used their CPAP also increased their physical activity levels.

Similar to the study by Batool-Anwar and colleagues (2014), Bamberga and colleagues (2015) also attempted to understand the relationship between CPAP use and physical activity levels. In their study, 107 obese OSA patients were recruited and received CPAP for 6 months. Physical activity levels were gauged before and after the

study via questionnaires. No increase in physical activity was found, directly contrary to the study by Batool-Anwar and colleagues (2014).

Numerous studies have relied on unvalidated physical activity questionnaires to make claims about the OSA population and some studies have unsurprisingly produced conflicting results (Batoll-Anwar et al., 2014 and Bamberga et al., 2015). This begs the question of whether physical activity questionnaires are a valid measure of physical activity levels within the OSA population. It is possible that factors discussed previously, such as sedentary lifestyles and sleepiness resulting in a lack of concentration may impede the ability of those with OSA from accurately taking physical activity questionnaires. Thus, the validity of different physical activity questionnaires within the OSA population must be examined in order to determine if it is appropriate to continue to gauge activity levels of OSA patients through questionnaires.

When determining which questionnaires to examine, one must consider the limited amount of time that exists within clinical settings and that patients typically come from varying educational backgrounds (Smith et al., 2005; Glasgow et al., 2005). This would imply that effective questionnaires must be both short and applicable to the population as a whole, especially those with low health literacy. Two questionnaires which appear promising in being concise and containing questions which are common across the general population are the International Physical Activity Questionnaires – short form (IPAQ-SF) and Physical Activity Vital Sign (PAVS) (Pereira et al., 1997; Marshall et al., 2003; Ball et al., 2016).

IPAQ-SF. While there are numerous questionnaires which measure physical activity in adults, not many meet the criteria of being short and containing questions

which are common across the general population (Marshall et al., 2003). The International Physical Activity Questionnaire (IPAQ) was developed with these problems in mind and was formulated to analyze physical activity levels based on universal standards (Craig et al., 2003). The IPAQ has since become one of the most widely used questionnaires for measuring physical activity (Poppel et al., 2010). Presently there is a short and long version of the IPAQ available for use.

Both the short and long form ask questions pertaining to the type and amount of physical activity done over the course of the previous 7 days. The major difference between the two forms is the short form only records absolute levels of each type of physical activity and the long form stratifies activity types into either job related, transportation, housework, or recreation. Due to the simpler nature of the short form, it is more appropriate for a clinical setting where time is limited (Smith et al., 2005; Glasgow et al., 2005). Many studies have been conducted on the IPAQ-SF to determine its reliability and criterion validity by correlating its results with an objective measure of accelerometry and have found the IPAQ-SF to be reliable and valid (Lee et al., 2011).

In a large population study by Craig and colleagues (2003) the IPAQ-SF was examined for reliability and validity across 12 countries within 18-65-year-old adults. The study analyzed reliability by giving participants the questionnaire two times over the course of one week and found strong reliability (Spearman's ρ values clustered around 0.80). Validity was examined by comparing the IPAQ-SF results with accelerometry from over the course of one week and had a median of $\rho = 0.3$, which the authors suggested was acceptable compared to exiting self-report questionnaires, especially when considering the diversity of the sample.

A study by Vandelanotte and colleagues (2005) recruited fifty-three 18-65 year old adults in order to analyze the reliability and validity of the IPAQ-SF. In this study each participant completed a computerized and paper version of the IPAQ-SF on three separate occasions and wore an accelerometer over the course of 7 days in order to collect objective data. The study found moderate to strong reliability (ICC between 0.60 to 0.83) and moderate validity of the IPAQ-SF ($r = 0.38$).

In a study by Scheeres and colleagues (2009) the validity of the IPAQ-SF was examined in patients with chronic fatigue syndrome. This population presents similar characteristics to the OSA population in terms of fatigue. When comparing the results of the IPAQ-SF with accelerometry, moderate validity was found ($\rho = 0.33$).

A study by Ekelund and colleagues (2006) recruited 185 adults between the ages of 20-69 to examine the validity of the IPAQ-SF. All participants wore an accelerometer for seven consecutive days and completed the IPAQ-SF on the eighth day. When IPAQ-SF data was compared to accelerometry data, moderate validity was found.

A study by Igelstrom and colleagues (2013) examined the validity of the IPAQ-SF within the obese OSA population. The study recruited 39 participants who were obese and had moderate to severe OSA. Each participant completed the IPAQ-SF after completing 5 days of activity tracking with an accelerometer. While the study did not find a strong relationship between the IPAQ-SF and accelerometry, the study may have been inaccurate for multiple reasons. It did not use ActiGraphy and rather used an armband which has been shown to not be as valid as hip worn accelerometry. The study also only tracked five days of activity when the IPAQ-SF asks about the previous seven days of activity.

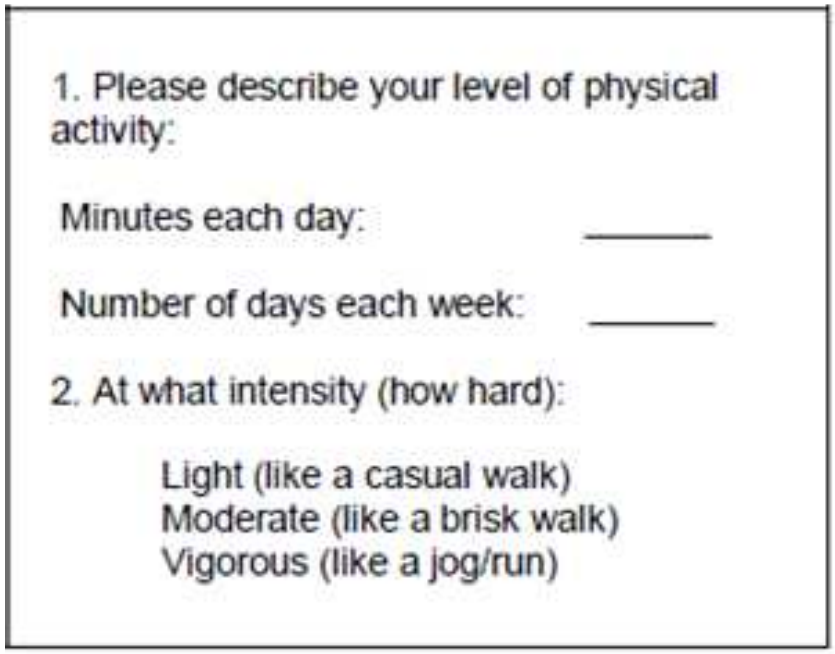
PAVS. Another questionnaire which has proven to be valid within the general population is the Physical Activity Vital Sign (PAVS) questionnaire (Coleman et al., 2012; Ball et al., 2015; Ball et al., 2016; Ball et al., 2016). The PAVS is a self-reported physical activity questionnaire that records the type and amount of physical activity performed over the previous 7 days. Presently two different versions of the PAVS exist. The first version of the PAVS asks two questions to patients, which are "On average, how many days per week do you participate in moderate or greater physical activity (like a brisk walk)?" and "On those days, how many minutes do you participate at that level?". Physical activity levels are then quantified by multiplying activity performed in minutes per day by average days a week.

A newer second version of the PAVS, depicted in figure 2, was recently developed to stratify activity type rather than simply look at total activity (Bal et al., 2016). The second PAVS records the type and amount of physical activity performed over the previous 7 days by asking three questions which are "Please describe your level of physical activity by minutes per day", "number of days each week" and "at what intensity (how hard): light (like a casual walk), moderate (like a brisk walk), or vigorous (like a jog/run)?".

Compared to the IPAQ-SF, the PAVS is a relatively new physical activity questionnaire with fewer studies that have examined its validity and reliability. Research that has examined the PAVS demonstrates promise. The PAVS usefulness within clinical settings is well established as demonstrated by its use within the Kaiser and Intermountain Health healthcare systems.

In a study by Ball and colleagues (2016) 45 healthy adults were recruited to examine the criterion validity of the PAVS. Participants wore an accelerometer for seven consecutive days followed by the completion of the PAVS. PAVS data were compared to the accelerometry data and strong validity were found (r = 0.52). The PAVS has also been studied by Coleman and colleagues (2012) to determine its construct validity by comparing its results with BMI and disease burden. This study examined the medical records of 1,793,385 adults 18 and older and found that those who exercised less had higher disease burden and BMI.

Figure 2. PAVS



Physical Activity Logbooks

Physical activity logbooks (or diaries) have long been used as a means to evaluate physical activity levels in a variety of populations (Reiff et al., 1967; Sallis, 1991; Tager et al., 1998; Sternfeld et al., 1999). In general, the process typically requires participants

to log their physical activity in real time in terms of type, frequency, intensity, and duration.

Previous research has indicated there are a variety strengths and weaknesses to utilizing logbooks to measure physical activity (Ainsworth, 2009; Sylvia et al., 2013). One major benefit to their utilization is that they are less susceptible to recall errors when compared to self-report questionnaires (Sylvia et al., 2013). They also provide detailed records of activity that self-report questionnaires are not capable of giving (Ainsworth, 2009; Sylvia et al., 2013). Additionally, they provide context to objective physical activity measures when utilized simultaneously (Hagstromer et al., 2006; Igelstrom et al., 2013). Some limitations to their use are that they can be time consuming and have been shown to result in large over predictions of moderate to vigorous physical activity (Buchowski et al., 1999; Hagstromer et al., 2006; Igelstrom et al., 2013). A review of the published literature identifies three studies that have examined the accuracy of logbooks as a means to assess physical activity within OSA and overweight populations.

A study by Buchowski and colleagues (1999) recruited 115 normal and overweight males and females. All participants spent a full day inside a whole room indirect calorimeter. Participants were instructed to exercise throughout the day and keep a log of the intensity, type, and duration of activity. The logbook results were converted into energy expenditure by the Compendium of Physical Activity and compared to indirect calorimetry (Ainsworth et al., 1993). The study found that with increasing body fat percentage, over predictions of energy expenditure from moderate to vigorous physical activity increased. On average, obese participants over predicted energy expenditure from moderate to vigorous physical activity by 100% when compared to

indirect calorimetry. This study suggests that physical activity logbooks may result in over predictions of moderate to vigorous physical activity, particularly in overweight and obese adults.

A study by Hagstromer and colleagues (2006) recruited 46 middle aged sedentary adults to test the criterion validity of the IPAQ-SF against accelerometry over the course of one week. In this study, participants were also asked to keep a daily physical activity log that included the time, type, intensity, and duration of the activity. Instead of providing a minute by minute comparison of the logbook versus the accelerometer, the study transformed the logbook activity into metabolic equivalent of tasks (METs). The study found that the logbook over predicted total MET hours per week by over five hours. While the logbook did provide additional context to the type of activity being performed as well as when activity took place during the day, the degree of its over prediction suggests that it may not be an effective means of assessing physical activity within a middle-aged sedentary population.

The only study we could identify that utilized a physical activity logbook within the OSA population was by Igelstrom and colleagues (2013) who recruited thirty-nine OSA patients with moderate to severe OSA. Similar to the study by Hagstromer and colleagues (2006), the study examined the validity of the IPAQ-SF against accelerometry and additionally asked participants to log the time, type, intensity, and duration of physical activity throughout the course of a five day period which was then averaged to create seven days of total activity. This study provided a minute by minute comparison of moderate to vigorous physical activity from the logbook and accelerometry and found that participants estimated that they completed 69 minutes of moderate to vigorous

physical activity per day when the accelerometer found that they completed 37 minutes per day. This equated to a 32 minutes per day or 3.7 hour per week over prediction of moderate to vigorous physical activity. The results of this study are similar to the results of the studies by Buchowski and colleagues (1999) and Hagstromer and colleagues (2006) which found that logbooks over predict total energy expenditure from moderate to vigorous physical activity when compared indirect calorimetry and accelerometry.

In conclusion, studies examining logbooks as a means to assess physical activity levels within OSA and overweight populations have found consistent over predictions of moderate to vigorous physical activity when compared to objective measures. While logbooks do provide additional context to the type of activity being performed at different times of the day and week, they are likely most beneficial if combined with and observed next to an objective physical activity measure.

Summary

OSA is a serious health disorder with debilitating effects on overall health. While the etiology of OSA is complex, excess body weight and physical inactivity have been shown to be the strongest risk factors. While CPAP, the most common treatment for OSA, is effective in treating many of side effects of OSA, it is not well adhered to and has been shown, at a minimum, not to promote weight loss. This is concerning due to the fact that excess body weight is the number one risk factor for OSA, and results in many of same metabolic disorders and cardiovascular disease which OSA is associated with or causes. Research has demonstrated that increased physical activity levels maintain or decrease body weight while significantly decreasing the severity of OSA, even when body reductions are not realized. In this regard, combining recommendations for exercise

and physical activity with CPAP may be a viable means to treat the major side effects of OSA and at a minimum ensure the underlying cause does not get worse. Increased activity levels would also reduce secondary risk factors that place patients at increased risk for worsening of their OSA, metabolic disorders, and cardiovascular disease.

While physical activity questionnaires are presently the most common method for assessing physical activity levels of those with OSA, no questionnaire has been validated specifically within the OSA population. Due to their short and simple nature, the IPAQ-SF and PAVS appear to be promising questionnaires for use in the OSA population. Both questionnaires have been shown to be reliable and valid within healthy populations but have yet to be thoroughly evaluated within the OSA population.

Having a validated physical activity questionnaire would provide a quick and inexpensive tool for clinicians to accurately determine the amount and patterns of physical activity within OSA patients. This would benefit the patients in allowing to get a clear picture of their activity levels as well as the clinician in determining how to proceed with appropriate protocols for treatment. It could also serve as a measure for both physicians and researchers to determine if future protocols aimed at increasing physical activity levels of OSA patients are effective.

Chapter 3: Methods

Introduction

This study aimed to assess the validity and reliability of physical activity questionnaire within the OSA population. Chapter two outlined the current literature to support a need for research in this area. To this date, no study had examined the validity of the PAVS within the OSA population. The study that did examine the validity of IPAQ-SF had many flaws (Igelstrom et al., 2013). The review of literature supports the following design.

Research Design

The study design allowed for investigation of the criterion validity, construct validity, and reliability of the IPAQ-SF and PAVS within an OSA population. The study used a descriptive correlation research design. Criterion validity was examined by determining the relationship between the IPAQ-SF and PAVS, which served as the subjective measures, and accelerometry data collected over the course of one week, which served as the objective measure. The data were assessed using Pearson correlation coefficients.

Construct validity was determined by examining the relationship between the IPAQ-SF and PAVS with BMI, CPAP adherence, OSA disease severity, sleepiness, and quality of life. The data were assessed by Spearman rank correlation coefficient. Reliability of the IPAQ-SF and PAVS was determined by having OSA patients complete the questionnaires twice at least seven days apart. These data were assessed by a two-way mixed, single measure, parametric intraclass correlation (ICC).

Specific Aim 1: To assess the criterion validity of the IPAQ-SF, PAVS, and logbook within an OSA population by comparing their results with an objective measure of accelerometry over the course of one week.

Hypothesis 1. IPAQ-SF, PAVS, and logbook will correlate strongly with one week of accelerometry data from individuals with OSA.

Specific Aim 2: To determine reliability of the IPAQ-SF and PAVS within an OSA population through a test retest design.

Hypothesis 2. IPAQ-SF and PAVS will show strong reliability when taken two times separated by at least one week.

Specific Aim 3: To determine construct validity of the IPAQ-SF, PAVS, and logbook within an OSA population by comparing the results of the questionnaires with BMI, sleepiness, OSA disease severity, CPAP adherence, sedentary time, and quality of life.

Hypothesis 3. Individuals with OSA that have lower levels of physical activity as indicated by the IPAQ-SF and PAVS will have a higher BMI, disease severity, and sleepiness while having a lower sleep quality and CPAP adherence.

Specific Aim 4: To determine the relationship between objective physical activity levels and BMI, sleepiness, OSA disease severity, CPAP adherence, and quality of life.

Hypothesis 4. Individuals with OSA that have lower levels of physical activity as indicated by accelerometry will have a higher BMI, disease severity, and sleepiness while having a lower sleep quality and CPAP adherence.

Population and Sample

Participants. Following approval by the institutional review board, a convenience sample of 40 individuals with OSA between the ages of 18-65 were recruited as the experimental group. Participants were recruited from the Indianapolis area through word of mouth, email, flyers, and the assistance of Indiana Clinical and Translational Sciences Institute (CTSI)". Interested participants were requested to contact the researcher via email to determine eligibility and to schedule an appointment to begin the study.

Inclusion and Exclusion Criteria. Inclusion criteria for participation in the study included individuals: (a) who were male or female between 18-65 years of age, (b) who could read and write English, (c) who had been diagnosed with moderate to sereve OSA (AHI $\geq$ 15). Exclusion criteria included individuals: (a) not meeting the above criteria, (b) with recent or chronic restrictive musculoskeletal injury (i.e. fractures, severe sprains or strains, dislocations, subluxations, or connective tissue injury), (c) those diagnosed with memory problems or diseases.

Instrumentation

IPAQ short form. The IPAQ-SF is a seven-item self-report physical activity questionnaire. The questionnaire assesses physical activity levels during the previous seven days. Frequency and duration of vigorous, moderate, and walking activity are assessed. The total physical activity time spent at different intensities are determined by multiplying the frequency and duration of each. Total physical activity time over the course of the week is calculated by adding all categories.

PAVS. The PAVS is a self-report physical activity questionnaire that records the type and amount of physical activity performed over the previous seven days. Presently two different versions of the PAVS exist. The initial version of the PAVS asks two questions to patients, which are "On average, how many days per week do you participate in moderate or greater physical activity (like a brisk walk)?" and "On those days, how many minutes do you participate at that level?". Physical activity levels are then quantified by multiplying activity performed in minutes per day by average days a week.

The more recent version of the PAVS, which was used in the current study, was altered to be more specific to the type of physical activity being done (Ball et al., 2013). This version consists of three questions which are "Please describe your level of physical activity by minutes each day and number of days each week" and "at what intensity (how hard): light (like a casual walk), moderate (like a brisk walk), or vigorous (like a jog/run)?" Physical activity levels are then quantified by multiplying the type of activity performed in minutes per day by average days a week.

ActiGraph. Accelerometry is the most commonly used objective measure for the determination of physical activity levels, with numerous studies demonstrating its validity (Freedson et al., 1998; Hendelman et al., 2000; Rothney et al., 2008; Sasaki et al., 2011). The ActiGraph wGT3X-BT (ActiGraph, LLC, Pensacola, Florida, USA) was the accelerometer used in the study. The ActiGraph is a 3-axis hip-worn accelerometer (4.6 cm x 3.3 cm x 1.5 cm, with a weight of 19 grams) that records accelerations ranging from 0.05 to 2 *g*. The ActiGraph is initialized and downloaded by ActiLife 6 software. Studies have demonstrated that the ActiGraph is valid by showing strong correlation with energy expenditure during daily activity. The ActiGraph has also been shown to have

strong test-retest reliability (ICC = 0.80), and when it is worn for seven consecutive days, physical activity can be assessed with 90% reliability. The ActiGraph does not provide the user with any feedback, and the ActiGraphs used in this study was calibrated by the manufacturer prior to the start of the study. (Sasaki et al., 2011; Santos-Lozano et al., 2013).

Health Related Quality of Life. The Healthy Days core questionnaire is a 4-item questionnaire created by the Center for Disease Control and Prevention to examine quality of the life. The questionnaire asks about mental and physical quality. Specifically, participants list the number of days in the previous month where they felt physically or mentally unhealthy. The questionnaire provides a score between 0 and 30 days, with scores closer to zero indicating a higher quality of life and scores closer to 30 indicating a lower quality of life. The questionnaire has been used in the State-based Behavioral Risk Factor Surveillance System since 1993, in the National Health and Nutrition Examination Survey since 2000, and in the Medicare Health Outcome Survey since 2003 (CDC, 2019). For this reason, the questionnaire was used in the study to determine if a relationship between more severe OSA and a lower quality of life.

Epworth Sleepiness Scale. The Epworth sleepiness scale is a questionnaire designed by Dr. Murray Johns in 1990 (Johns, 1991). The questionnaire was named after Epworth hospital in Melbourne Australia. In designing the questionnaire, Johns' intent was to create a tool, which could accurately assess daytime sleepiness. The questionnaire presents eight different circumstances which patients must rank their likeness of dozing off in. Patients rank on a four-point scale (0-3) with a score of zero indicating no chance of dozing off and a score of three indicating a high chance of dozing off. The

questionnaire results in a score between zero and 24, with scores closer to zero indicating low levels of sleepiness and scores closer to 24 indicating high levels of sleepiness.

Studies examining the Epworth Sleepiness scale have found it be reliable with intraclass correlation coefficients between 0.81 and 0.93 (Gibson et al. 2006; Izci et al. 2007; Cho et al 2011; van der Heide et al. 2015). In terms of the relationship between the Epworth Sleepiness Scale and OSA, studies have found both statically significant and statically non-significant relationships (Manni et al 1999; Guilleminault et al, 1988). Nonetheless, the scale is used frequently to help predict the likeliness of whether a patient will be diagnosed with OSA. For this reason, the questionnaire was used in the study to examine if a relationship between physical activity levels and sleepiness existed.

Study Procedures

Initial contact. Patients were informed about the study through word of mouth, flyers, and the assistance of Indiana Clinical and Translational Sciences Institute (CTSI). Interested participants contacted the researcher through email. The researcher then determined eligibility of the potential participant. If eligible, the participant made two separate visits, which were both conducted by the researcher.

First Visit. Upon arrival to the laboratory on the first visit, participants were provided voluntary written informed consent which can be found in appendix 9. Following consent, participants then completed the IPAQ-SF and PAVS. Each participant was then fitted with a belt around the waist that served as the attachment point for the ActiGraph. Participants were instructed to wear the ActiGraph, which was initialized at a sample rate of 30 Hz to record activities for free-living conditions, over their right iliac crest during all waking hours for the next seven consecutive days, except

when showering, bathing or swimming. Participants were instructed to remove the ActiGraph when going to bed at night and to record what time they put on and removed the ActiGraph each day onto a log sheet.

Construct Validity. The PAVS and IPAQ-SF were examined for construct validity by comparing the questionnaires with BMI, sleep quality, OSA disease severity, treatment adherence, and quality of life. In order for the researcher to access this information, each participant completed an authorization for the release of health information for research form. This form was provided to the participants' doctor who provided the information needed for the determination of construct validity.

Second visit. Following the seven days, participants met with the researcher a second time to return the Actigraph, and complete the IPAQ-SF and PAVS for the second time.

Data Analysis

SPSS version 26 (IBM, Richmond, Virginia) was used for data analysis. Differences in age, BMI, and activity levels were examined between genders using independent t-tests. Accelerometry data were downloaded and analyzed using ActiLife 6 software (ActiGraph, LLC, Pensacola, Florida, USA). Waking minutes from the ActiGraph were cleaned by application of a separate non-wear algorithm to identify valid wear time during waking hours. Participants with a wear time corresponding to at least 10 hours during waking time per day (i.e., ≥600 total wear min/day), collected over seven full days or more were included in analyses. Counts per minute were summed across seven days in order to determine total hours and minutes of activity over the course of the week. As depicted in table 1, the Freedson cut-points (light <1952 counts/minute,

moderate 1952–5724 counts/minute, vigorous > 5725 counts/ minute) were used to stratify intensities (Freedson et al., 1998). These cut-points were used because the moderate intensity category is calibrated to walking, which is the most common type of ambulatory activity. Because the current physical activity recommendations no longer indicate that physical activity must be accumulated in bouts of at least 10 minutes, the data were examined as a whole to determine the number of minutes per day spent in moderate and vigorous physical activity and not just those that occur in bouts of at least 10 minutes.

Table 1. Freedson cut points

Counts Per Minute	Activity Level
Less than 1952	Light
1952 – 5724	Moderate
Greater than 5725	Vigorous

Criterion validity. Criterion validity of the IPAQ-SF and PAVS was assessed by Pearson correlation coefficient. Results of the IPAQ-SF and PAVS were compared with physical activity data as collected by the ActiGraph ($r < 0.3$ = None or very weak, $0.3 < r < 0.5$ = small $0.5 < r < 0.7$ = Moderate, $r > 0.7$ = strong) (Hojat and Xu, 2004). Judgements of the significance of the correlations were further examined using Bland-Altman plots (Bland and Altman, 1986). The Bland-Altman plots provided indication of the systematic and random error and heteroscedasticity of the data and 95% limits of agreement for describing the total error between the questionnaires and ActiGraph.

Reliability. Reliability of the I-PAQ-SF and PAVS was assessed by a two-way mixed, single measure, parametric intraclass correlation (ICC) (ICC < 0.5 = poor, 0.5 < r <0.75 = moderate, 0.75 < r < 0.9 = good, r > 0.9 = excellent) (Bartko, 1976).

Construct Validity. Construct validity of the I-PAQ-SF and PAVS was assessed by Spearman rank correlation coefficient (ρ). Results of the IPAQ-SF and PAVS were compared with BMI, OSA severity, CPAP adherence, quality of life, and sleepiness (ρ < 0.3 = None or very weak, 0.3 < ρ <0.5 = small 0.5 < ρ < 0.7 = moderate, ρ > 0.7 = strong) (Hojat and Xu, 2004).

Sample Size. A power analysis was performed for the determination of sample size and is depicted in table 2. For the determination of construct and criterion validity, effect size was set at 0.5 which was based on existing research where the correlation coefficients for the IPAQ-SF and PAVS when compared to accelerometry data averaged 0.5 (Ball et al., 2014). Level of significance was set at less than 5 percent, and power was set at 80%. It was determined that a minimum of 37 participants were required for the current study in order achieve the necessary power.

Table 2. Power Analysis

Measure	A Priori
Effect Size	0.5 Medium
Alpha (α)	0.05
Power (1-β)	0.80
Sample size total	37

Chapter 4: Results

Introduction

A schematic of participant enrollment and adherence is shown in figure 3. Between March and July 2019, a total of 40 participants were enrolled (Figure 3). After examining the raw data, one participant did not meet the minimum criteria for accelerometry wear time and was excluded from all data analyses. The participant was asked to wear the accelerometer for an additional seven days but did not have an interest in doing so. A total of 39 participants completed the study with adequate amounts of wear time. The measures and associated statistical tests are listed in table 3.

Figure 3. Participant enrollment and adherence

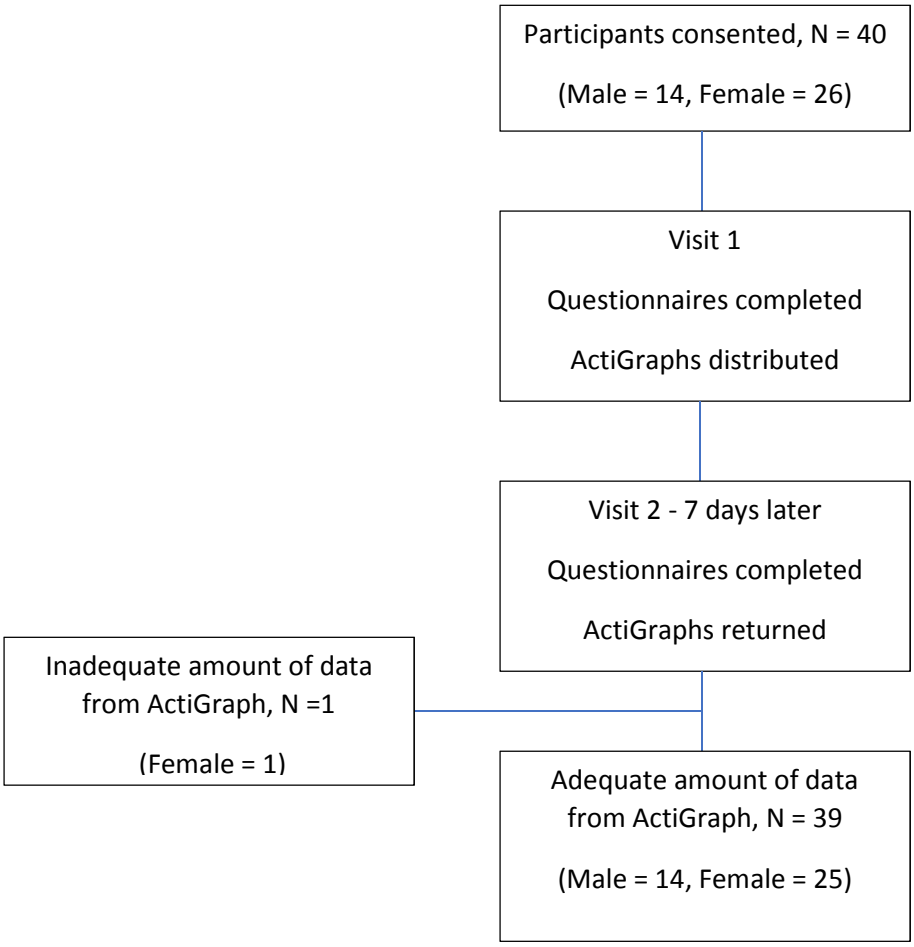


Table 3. Statistical analysis for each measure

Type of measure	**Comparison**	**Analysis**
Criterion validity	IPAQ-SF visit 2 versus ActiGraph	Pearson correlation Bland Altman plot
Reliability	IPAQ-SF visit 1 versus visit 2	two-way mixed, single measure, parametric intraclass correlation
Construct validity	IPAQ-SF visit 2 versus variables related to the outcome	Spearman correlation
Criterion validity	PAVS visit 1 versus ActiGraph	Pearson correlation Bland Altman plot
Reliability	PAVS visit 1 versus visit 2	two-way mixed, single measure, parametric intraclass correlation
Construct validity	PAVS visit 2 versus variables related to the outcome	Spearman correlation
Criterion validity	Logbook versus ActiGraph	Pearson Correlation Bland Altman plot
Construct validity	Logbook versus variables related to the outcome	Spearman correlation
Exploratory	ActiGraph versus variables related to the outcome	Spearman correlation

Sample

Descriptive statistics for participants are reported in table 4. There were 14 males and 25 females for a total of 39 participants. The age range for participants was between 25 and 65 years with an average age of 51.5 ± 9.5 years. All participants were either overweight or obese with the BMI ranging between 27 and 61 and averaging 39.1 ± 8.8. All participants had moderate to severe OSA, with AHI values ranging between 15 and 128, and averaging 40.4 ± 29.3. Unhealthy days for participants ranged between 0 and 30 days per month and averaged 11.6 ± 11.7. Sleepiness levels ranged between 0 and 20 and averaged 8.1 ± 4.8. Every participant in the study scored 10 out of 10 on the cognitive

impairment questionnaire. The descriptive statistics indicated normal distribution for age, BMI, OSA severity, and physical activity levels. There were no significant gender differences regarding age ($p = 0.88$), BMI ($p = 0.71$), or time spent in moderate-to-vigorous activity ($p = 0.63$) as reported by the questionnaires or ActiGraph. Consequently, the genders were pooled in analyses.

Table 4. Characteristics of participants, $n = 39$

Male	14
Female	25
African American	12
Caucasian	27
Age (years)	51.5 ± 9.5
Height (cm)	168.7 ± 10.6
Weight (kg)	111.3 ± 21.8
Body Mass Index	39.1 ± 8.8
Time Since Diagnosis	.7 ± 1.8
ActiGraph Wear Time (h week^{-1})	14 ± 3.7
OSA Severity (AHI)	40.4 ± 29.3
Quality of Life* (QofL) (unhealthy days)	11.6 ± 11.7
CPAP Adherence (h week^{-1})	38.63 ± 21.6
Sleepiness**	8.1 ± 4.8
Cognitive Impairment***	10 ± 0

Values are expressed as mean ± standard deviation (except for frequencies)
*QofL measured by the Health Days Questions (range: 0-30)
**Sleepiness measured by the Epworth Sleepiness Scale (range: 0-24)
*** Cognitive impairment measured by the Short Portable Mental Status Questionnaire (0-10)

Specific Aim 1. To assess the criterion validity of the IPAQ-SF, PAVS, and logbook within an OSA population by comparing their results with an objective measure of accelerometry over the course of one week.

Since both the questionnaires and ActiGraph measured weekly activity in minutes per week, which are discrete variables, Pearson correlations were used to assess the validity of the questionnaires and logbook by comparing their results with physical activity data collected by the ActiGraph. Moderate, vigorous, and moderate-to-vigorous

physical activity levels were determined by adding together activity types as written on the questionnaires. Activity levels from the ActiGraph were determined by downloading the raw data and running it through ActiLife 6 software using the 1998 Freedson cut points which stratified activity levels into moderate, vigorous, and moderate-to-vigorous.

Descriptive and correlational results for the IPAQ-SF are reported in tables 5 and 6. For the IPAQ-SF, moderate activity levels were 332.8 ± 481.7 minutes a week, while moderate activity levels from the ActiGraph were 109.1 ± 122.2 minutes per week. This resulted in a Pearson correlation coefficient of 0.406 and a p value of 0.01 for moderate activity. Vigorous activity levels as measured by the IPAQ-SF were 121.7 ± 403.3 minutes per week, while vigorous activity levels from the ActiGraph were 1.6 ± 5.1 minutes per week. This resulted in a Pearson correlation coefficient of 0.02 and a p value of 0.919 for vigorous activity. Moderate-to-vigorous activity levels measured by the IPAQ-SF were 454.5 ± 772 minutes per week, while moderate-to-vigorous activity levels measured by the ActiGraph were 110.8 ± 124.9 minutes per week. This resulted in Pearson correlation coefficient of 0.569 and a p value of <0.001 for moderate-to-vigorous activity

Table 5. Descriptive data from the IPAQ-SF and ActiGraph

	IPAQ-SF	ActiGraph
Total MVPA (min week $^{-1}$)	454.5 ± 772	110.8 ± 124.9
Moderate PA (min week $^{-1}$)	332.8 ± 481.7	109.1 ± 122.2
Vigorous PA (min week $^{-1}$)	121.7 ± 403.3	1.6 ± 5.1

Values are expressed as mean ± standard deviation

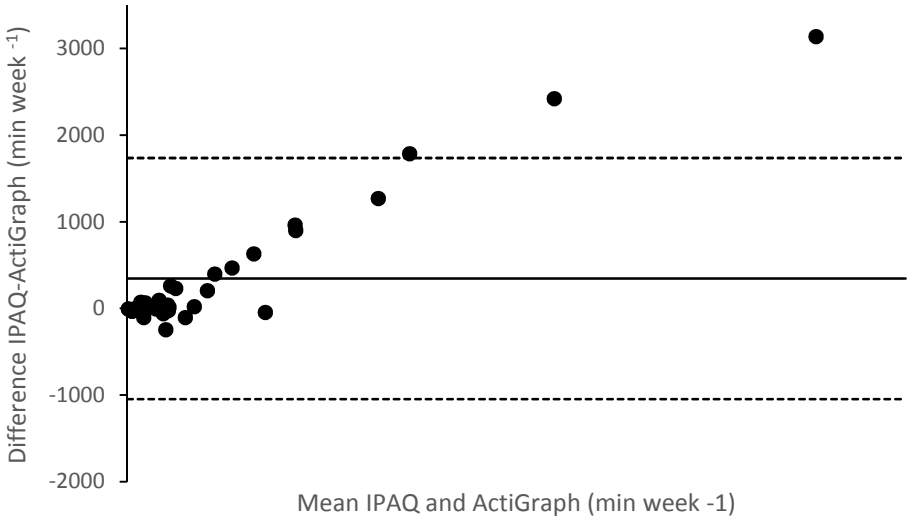
Table 6. Pearson correlation coefficients PAVS and ActiGraph

IPAQ-SF vs ActiGraph	*r*
Total MVPA	0.569***
Moderate PA	0.406**
Vigorous PA	0.02

**, P < 0.01; ***, P < 0.001

A Bland-Altman plot (figure 4) was created to analyze moderate-to-vigorous activity from the IPAQ-SF and ActiGraph. The analysis showed that the mean difference between the IPAQ-SF and ActiGraph for moderate-to-vigorous physical activity was 345.8 minutes per week, indicating participants generally overestimated their moderate-to-vigorous physical activity levels by over 4-fold using the IPAQ-SF. The 95% limits of agreement were wide, ranging from -1045.7 to 1737.4 minutes per week.

Figure 4. Bland Altman plot for IPAQ-SF vs ActiGraph



Descriptive and correlational results for the PAVS are reported in tables 7 and 8. For the PAVS, moderate activity levels measured 112.1 ± 156.9 minutes per week, while moderate activity measured from the ActiGraph were 109.8 ± 122.4 minutes per week. This resulted in a Pearson correlation coefficient of 0.693 and p value of <0.001 for moderate activity. Vigorous activity levels as measured by the PAVS were 46.1 ± 230.1

minutes per week, while vigorous activity levels from the ActiGraph were 1.6 ± 5.1 minutes per week. This resulted in a Pearson correlation coefficient of 0.04 and p value of 0.815 for vigorous activity. Moderate-to-vigorous activity levels as measured by the PAVS were 159.3 ± 337.2 minutes per week, while moderate-to-vigorous activity levels from the ActiGraph were 111.3 ± 125.2 minutes per week. This resulted in a Pearson correlation coefficient of 0.802 and p value of <0.001 for moderate-to-vigorous activity.

Table 7. Descriptive data from the PAVS and ActiGraph

	PAVS	ActiGraph
Total MVPA (min week $^{-1}$)	159.3 ± 337.2	110.8 ± 124.9
Moderate PA (min week $^{-1}$)	112.1 ± 156.9	109.1 ± 122.2
Vigorous PA (min week $^{-1}$)	46.1 ± 230.1	1.6 ± 5.1

Values are expressed as mean ± standard deviation

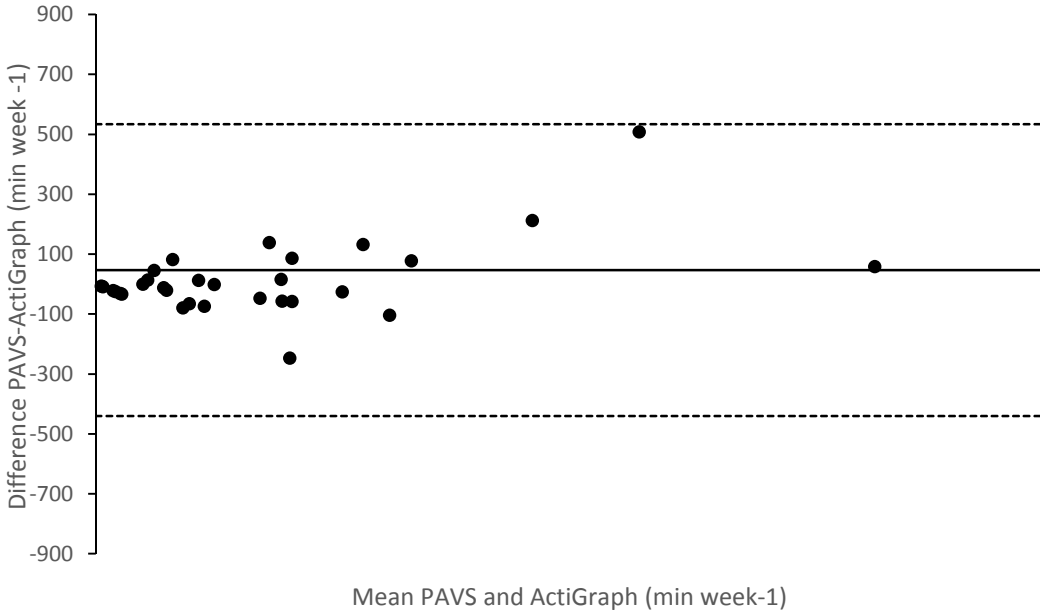
Table 8. Pearson correlation coefficients for PAVS and ActiGraph

PAVS vs ActiGraph	*r*
Total MVPA	0.802***
Moderate PA	0.693**
Vigorous PA	0.04

**, P < 0.01; ***, P < 0.001

A Bland-Altman plot (figure 5) was created to analyze moderate-to-vigorous activity from the PAVS and ActiGraph. The analysis showed that the mean difference between the PAVS and ActiGraph was 46.8 minutes per week, with PAVS overestimating moderate-to-vigorous activity by 43%. The 95% limits of agreement ranged from -440.7 to 534.4 minutes per week.

Figure 5. Bland Altman plot for PAVS vs ActiGraph



Descriptive and correlational results for the logbook are reported in tables 9 and 10. For the logbook, moderate-to-vigorous activity levels measured 302.6 ± 554.9 minutes per week, while moderate-to-vigorous activity levels from the ActiGraph were 111.3 ± 125.2 minutes per week. This resulted in a Pearson correlation coefficient of 0.59 and a p value of <0 0.001 for moderate-to-vigorous activity.

Table 9. Descriptive data from the logbook and ActiGraph

	Logbook	ActiGraph
Total MVPA (min week $^{-1}$)	302.6 ± 554.9	110.8 ± 124.9

Values are expressed as mean ± standard deviation

Table 10. Pearson correlation coefficients for logbook and ActiGraph

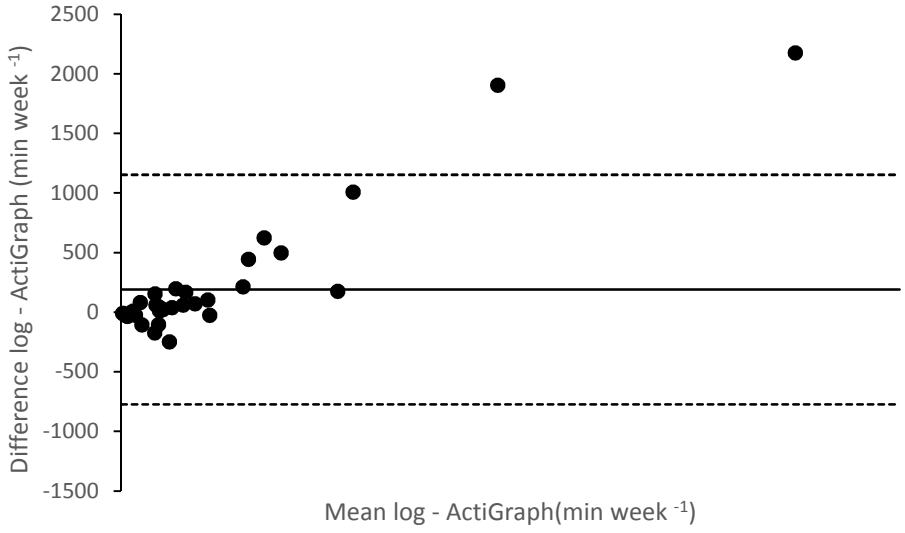
Logbook vs ActiGraph	*r*
Total MVPA	0.59***

***, P < 0.001

A Bland-Altman plot (figure 6) was created to analyze moderate-to-vigorous activity from the logbook and ActiGraph. The analysis showed that the mean difference

between the logbook and ActiGraph was 191.2 minutes per week. The 95% limits of agreement ranged from -772.3 to 1154.7 minutes per week.

Figure 6. Bland Altman plot for logbook vs ActiGraph



Specific Aim 2: To determine reliability of the IPAQ-SF and PAVS within an OSA population through a test retest design.

For aim 2, a two-way mixed, single measure, parametric intraclass correlation (ICC) was used to determine if the IPAQ-SF and PAVS were reliable when taken two times at least 7 days apart. Establishing reliability of the IPAQ-SF and PAVS within the OSA population was important because a questionnaire cannot be valid if it is not reliable.

The reliability statistics for the IPAQ-SF are reported in table 11. For the IPAQ-SF, moderate activity levels were estimated at 226.7 ± 409.2 minutes per week during the first visit and 332.8 ± 481.7 during the second visit, resulting in an ICC of 0.463 and 95% confidence intervals of lower bound -0.011 and upper bound 0.717. Vigorous activity levels were estimated at 118.6 ± 434 minutes per week during the first visit and 121.7 ± 403.3 during the second visit, resulting in an ICC of 0.892 and 95% confidence intervals

of lower bound 0.794 and upper bound 0.944. Moderate-to-vigorous activity levels were estimated at 345.3 ± 668.7 minutes per week during the first visit and 454.5 ± 772 during the second visit, resulting in an ICC of 0.766 and 95% confidence intervals of lower bound 0.557 and upper bound 0.877.

Table 11. Reliability of IPAQ-SF

	Administration one	Administration two	ICC	95% CI
MVPA	345.3 ± 668.7	454.5 ± 772	.766**	.557, 0.877
Moderate	226.7 ± 409.2	332.8 ± 481.7	.463**	0.011, 0.717
Vigorous	118.6 ± 434	121.7 ± 403.3	.892**	.794, 0.944

values are mean ± sd, *P < 0.05, **P < 0.01 between administrations

The reliability statistics for the PAVS are reported in table 12. For the PAVS, moderate activity levels were estimated at 98.0 ± 175.4 minutes per week during the first visit and 112.1 ± 156.9 during the second visit, resulting in an ICC of 0.922 and 95% confidence intervals of lower bound 0.853 and upper bound 0.959. Vigorous activity levels were estimated at 69.9 ± 338.2 minutes per week during the first visit and 46.1 ± 230.1 during the second visit, resulting in an ICC of 0.958 and 95% confidence intervals of lower bound 0.920 and upper bound 0.978. Moderate-to-vigorous activity levels were estimated at 167.9 ± 412.8 minutes per week during the first visit and 159.3 ± 337.2 during the second visit. This resulted in an ICC of 0.982 and 95% confidence intervals of lower bound 0.966 and upper bound 0.991.

Table 12. Reliability of PAVS

	Administration one	Administration two	ICC	95% CI
MVPA	167.9 ± 412.8	159.3 ± 337.2	.982**	.966, 0.991
Moderate	98.0 ± 175.4	112.1 ± 156.9	.922*	.853, 0.959
Vigorous	69.9 ± 338.2	46.1 ± 230.1	.958**	.920, 0.978

values are mean ± sd, *P ≤ 0.05, **P < 0.01 between administrations

Specific Aim 3: To determine construct validity of the IPAQ-SF, PAVS, and logbook within an OSA population by comparing the results of the questionnaires with BMI, sleepiness, OSA disease severity, CPAP adherence, sedentary time, and quality of life.

Because aim 3 is comparing a discrete variable in physical activity time against ranked variables, Spearman rank correlation coefficients were used. The Spearman correlation coefficients were run to determine if estimated physical activity levels from the questionnaires were related to factors related to OSA, such as BMI, disease severity, CPAP adherence, sleepiness, sedentary time, and quality of life. Establishing construct validity of the IPAQ-SF, PAVS, and logbook within the OSA population was important because it helped determine if the questionnaires were accurate in their overall assessment of an OSA patient.

All constructs compared to activity levels as reported by the IPAQ-SF are reported in table 13. For the IPAQ-SF, no significant correlations were found between moderate, vigorous, or moderate-to-vigorous physical activity and OSA severity, quality of life, CPAP adherence, or sleepiness. The significant correlations found were between moderate physical activity and BMI ($\rho = -0.279$, $p = 0.05$), and moderate-to-vigorous physical activity and BMI ($\rho = -0.268$, $p = 0.05$).

Table 13. Spearman correlation coefficients for IPAQ-SF versus construct

IPAQ-SF	*Construct measure*	ρ
Total MVPA (min week $^{-1}$)	BMI	0.268*
Moderate PA (min week $^{-1}$)	BMI	0.279*
Vigorous PA (min week $^{-1}$)	BMI	0.04
Total MVPA (min week $^{-1}$)	OSA severity	.032
Moderate PA (min week $^{-1}$)	OSA severity	.019
Vigorous PA (min week $^{-1}$)	OSA severity	.224
Total MVPA (min week $^{-1}$)	QofL	.072
Moderate PA (min week $^{-1}$)	QofL	.098
Vigorous PA (min week $^{-1}$)	QofL	0.111
Total MVPA (min week $^{-1}$)	CPAP Adherence	0.003
Moderate PA (min week $^{-1}$)	CPAP Adherence	.007
Vigorous PA (min week $^{-1}$)	CPAP Adherence	0.242
Total MVPA (min week $^{-1}$)	Sleepiness	.062
Moderate PA (min week $^{-1}$)	Sleepiness	.063
Vigorous PA (min week $^{-1}$)	Sleepiness	0.096

*, $P \leq 0.05$

All constructs compared to activity levels as reported by the PAVS are reported in table 14. For the PAVS, no significant correlations were found between moderate, vigorous, or moderate-to-vigorous physical activity and OSA severity, quality of life, CPAP adherence, or sleepiness. The significant correlations found were between moderate-to-vigorous physical activity and BMI ($\rho = -0.273$, $p = 0.05$), and vigorous physical activity and BMI ($\rho = -0.331$, $p = 0.05$)

Table 14. Spearman correlation coefficients for PAVS versus construct

PAVS	*Construct measure*	ρ
Total MVPA (min week $^{-1}$)	BMI	0.273*
Moderate PA (min week $^{-1}$)	BMI	.245
Vigorous PA (min week $^{-1}$)	BMI	0.331*
Total MVPA (min week $^{-1}$)	OSA severity	0.166
Moderate PA (min week $^{-1}$)	OSA severity	0.157
Vigorous PA (min week $^{-1}$)	OSA severity	0.112
Total MVPA (min week $^{-1}$)	QofL	0.042
Moderate PA (min week $^{-1}$)	QofL	0.097
Vigorous PA (min week $^{-1}$)	QofL	.03
Total MVPA (min week $^{-1}$)	CPAP Adherence	.024
Moderate PA (min week $^{-1}$)	CPAP Adherence	0.022
Vigorous PA (min week $^{-1}$)	CPAP Adherence	0.114
Total MVPA (min week $^{-1}$)	Sleepiness	.038
Moderate PA (min week $^{-1}$)	Sleepiness	0.058
Vigorous PA (min week $^{-1}$)	Sleepiness	.07

*, $P \leq 0.05$

All constructs compared to activity levels as reported by the logbook are reported in table 15. For the logbook, no significant correlations were found between moderate-to-vigorous physical activity and OSA severity, quality of life, CPAP adherence, or sleepiness. The significant correlations found were between moderate-to-vigorous physical activity and BMI ($\rho = -0.343$, $p = 0.033$)

Table 15. Spearman correlation coefficients for logbook versus construct

logbook	*Construct measure*	ρ
Total MVPA (min week $^{-1}$)	BMI	0.343*
Total MVPA (min week $^{-1}$)	OSA severity	.036
Total MVPA (min week $^{-1}$)	QofL	0.03
Total MVPA (min week $^{-1}$)	CPAP Adherence	.09
Total MVPA (min week $^{-1}$)	Sleepiness	0.080

*, $P \leq 0.05$

Specific Aim 4. To determine the relationship between objective physical activity levels and BMI, sleepiness, OSA disease severity, CPAP adherence, and quality of life.

Because aim 4 was comparing a discrete variable in objective physical activity time against ranked variables, Spearman rank correlation coefficients were used. The

Spearman correlation coefficients were run to determine if physical activity levels as measured by the ActiGraph were correlated to factors related to OSA, such as BMI, disease severity, CPAP adherence, sleepiness, sedentary time, and quality of life. These data were examined for the purpose of helping determine future areas of interest for research.

All data for constructs versus activity levels as reported by the ActiGraph are reported in table 16. No significant correlations were found between moderate, vigorous, or moderate-to-vigorous physical activity and OSA severity, quality of life, CPAP adherence, or sleepiness. The significant correlations found were between moderate physical activity and BMI ($\rho = 0.335$, $p = 0.034$) and moderate-to-vigorous physical activity and BMI ($\rho = 0.320$, $p = 0.042$).

Table 16. Spearman correlation coefficients for ActiGraph versus construct

Activity monitor	*Construct measure*	ρ
Total MVPA (min week $^{-1}$)	BMI	0.320*
Moderate PA (min week $^{-1}$)	BMI	0.335*
Vigorous PA (min week $^{-1}$)	BMI	0.204
Total MVPA (min week $^{-1}$)	OSA severity	0.190
Moderate PA (min week $^{-1}$)	OSA severity	0.191
Vigorous PA (min week $^{-1}$)	OSA severity	0.115
Total MVPA (min week $^{-1}$)	QofL	0.265
Moderate PA (min week $^{-1}$)	QofL	0.273
Vigorous PA (min week $^{-1}$)	QofL	.051
Total MVPA (min week $^{-1}$)	CPAP Adherence	0.118
Moderate PA (min week $^{-1}$)	CPAP Adherence	0.096
Vigorous PA (min week $^{-1}$)	CPAP Adherence	0.219
Total MVPA (min week $^{-1}$)	Sleepiness	.003
Moderate PA (min week $^{-1}$)	Sleepiness	.007
Vigorous PA (min week $^{-1}$)	Sleepiness	.027

*, $P \leq .05$

Summary of Findings

Table 17 provides a description of the research hypotheses and outcomes. The analyses indicated that the relationship between the IPAQ-SF and the ActiGraph was significant for moderate-to-vigorous physical activity with a moderate effect size ($r > .5$). The IPAQ-SF was not valid with low effect sizes ($r < .5$) for determining either moderate or vigorous physical activity. The relationship between the PAVS and the ActiGraph was significant for moderate and moderate-to-vigorous physical activity with a strong effect size for both. The PAVS was not valid for determining vigorous physical activity. The relationship between the logbook and the ActiGraph was significant for moderate-to-vigorous physical activity with a moderate effect size. Unlike the IPAQ-SF and PAVS, the logbook did not examine moderate and vigorous physical activity individually.

The reliability analysis indicated that the IPAQ-SF held good reliability for moderate-to-vigorous and vigorous physical activity with wide confidence intervals when taken twice over the course of 7 days. The IPAQ-SF was not reliable in determining moderate physical activity. The PAVS had excellent reliability for moderate, vigorous, and moderate-to-vigorous physical activity with narrow confidence intervals.

When examining construct validity, levels of moderate, vigorous, and moderate-to-vigorous activity as reported by the IPAQ-SF, PAVS, and logbook held no relationship with OSA severity, CPAP adherence, quality of life, or sleepiness. The only relationship the IPAQ-SF, PAVS, and logbook all held was with moderate-to-vigorous physical activity and BMI.

When comparing the accelerometry data to factors related to OSA, it was found that objective moderate, vigorous, and moderate-to-vigorous physical activity levels held

no relationship with OSA severity, CPAP adherence, quality of life, and sleepiness. The only relationship that objective physical activity levels held was with moderate-to-vigorous physical activity and BMI.

In reviewing the results for specific aim 1 and 3, the PAVS is the most valid and reliable questionnaire when compared to the IPAQ-SF and logbook for determining moderate and moderate-to-vigorous physical activity. The IPAQ-SF, PAVS, and logbook are not valid in determining vigorous physical activity levels. In terms of specific aim 2, the IPAQ-SF, PAVS, and logbook did not produce significant relationships with any physical activity level and OSA severity, CPAP adherence, quality of life, or sleepiness. The only relationship the IPAQ-SF, PAVS, and logbook held was with moderate-to-vigorous physical activity and BMI; however, the effect sizes were small. For specific aim 4, the objective physical activity levels as measured by the ActiGraph did not demonstrate relationships with any physical activity level and OSA severity, CPAP adherence, quality of life, or sleepiness. The only relationship objective physical activity levels did hold was with moderate-to-vigorous physical activity and BMI; however, the effect size was small.

Table 17. Research hypotheses and outcomes

Aim	Null hypothesis	Fail to reject	reject	Findings
1	The IPAQ-SF will not be moderately valid when measured against accelerometry for moderate-to-vigorous physical activity		×	The IPAQ-SF demonstrated moderate validity when compared to accelerometry for moderate-to-vigorous physical activity
1	The PAVS will not be moderately valid when measured against accelerometry for moderate-to-vigorous physical activity		×	The PAVS demonstrated strong validity when compared to accelerometry for moderate-to-vigorous physical activity
1	The logbook will not be moderately valid when measured against accelerometry for moderate-to-vigorous physical activity		×	The log book demonstrated moderate validity when compared to accelerometry for moderate-to-vigorous physical activity
2	The IPAQ-SF will not demonstrate good reliability for moderate-to-vigorous physical activity when taken two times over the course of 7 days		×	The IPAQ-SF did demonstrate good reliability for moderate-to-vigorous physical activity when taken two times over the course of 7 days
2	The PAVS will not demonstrate good reliability for moderate-to-vigorous physical activity when taken two times over the course of 7 days		×	The PAVS did demonstrate good reliability for moderate-to-vigorous physical activity when taken two times over the course of 7 days
3	The IPAQ-SF will not demonstrate moderate construct validity for moderate-to-vigorous physical activity when compared to factors related to OSA	×		The IPAQ-SF did not demonstrate moderate construct validity for moderate-to-vigorous physical activity when compared to factors related to OSA
3	The PAVS will not demonstrate moderate construct validity for moderate-to-vigorous physical activity when compared to factors related to OSA	×		The PAVS did not demonstrate moderate construct validity for moderate-to-vigorous physical activity when compared to factors related to OSA
3	The logbook will not demonstrate moderate construct validity for moderate-to-vigorous physical activity when compared to factors related to OSA	×		The logbook did not demonstrate moderate construct validity for moderate-to-vigorous physical activity when compared to factors related to OSA
4	Objective moderate-to-vigorous physical activity levels from the ActiGraph will not correlate with factors related to OSA	×		Objective moderate-to-vigorous physical activity levels from the ActiGraph did not correlate with factors related to OSA

Chapter 5: Discussion

Introduction

The main objectives of the study were to determine the validity and reliability of the IPAQ-SF and PAVS, as well as the validity of a physical activity logbook. Secondarily, the objective was to determine if the IPAQ-SF, PAVS, and logbook held construct validity when compared to factors related to OSA. Additionally, the relationship between objective physical activity levels were compared to factors related to OSA. As a result of conducting the study, the investigator added to the body of knowledge in physical activity questionnaire validity within the OSA population. The results from study have created a means for clinicians to get a better understanding of moderate and moderate to vigorous physical activity levels of OSA patients. The findings of the study also provide clinicians and researchers with a means to judge the effectiveness of protocols aimed at increasing physical activity levels in OSA patients.

Summary of Subjects

The study had an uneven distribution of males (14) and females (25), but males and females were similar to one another in terms of age, BMI, race, OSA severity, and subjective and objective physical activity levels.

Criterion Validity

In order to determine criterion validity, the results from the IPAQ-SF, PAVS, and logbook completed during the second visit were compared to the seven days of objective physical activity measured by the ActiGraph. With regard to the logbook, participants logged moderate-to-vigorous physical activity levels and did not record moderate and

vigorous physical activity levels individually. The validity analysis was performed with Pearson correlation coefficients.

The IPAQ-SF and PAVS did not produce significant results when compared to vigorous physical activity levels from the ActiGraph. The IPAQ-SF over predicted vigorous physical activity by 120.1 ± 403.3 minutes per week while the PAVS over predicted vigorous physical activity levels by 44.5 ± 229.9 minutes per week. These results indicate that the IPAQ-SF and PAVS may not be accurate in assessing vigorous physical activity.

When analyzing the validity of moderate physical activity levels, both the IPAQ-SF and PAVS produced significant results when compared to the ActiGraph. While both the IPAQ-SF and PAVS produced significant results, only the PAVS had an acceptable effect size. The IPAQ-SF over predicted moderate physical activity by 223.7 ± 446.3 minutes per week while the PAVS over predicted moderate physical activity by 2.3 ± 114 minutes per week. These results indicate that the PAVS may be the most accurate questionnaire for determining moderate physical activity levels in OSA patients.

When analyzing the validity of moderate-to-vigorous physical activity levels, the IPAQ-SF, PAVS, and logbook all produced significant results when compared to the ActiGraph. While all subjective forms of physical activity estimation produced significant results with at least moderate effect sizes, the PAVS was the only questionnaire to possess a strong effect size. The IPAQ-SF over predicted moderate-to-vigorous physical activity levels by 345.9 ± 710 minutes per week, while the PAVS over predicted moderate to vigorous physical activity levels by 46.8 ± 248.8 minutes per week, and the logbook over predicted moderate-to-vigorous physical activity by 191.2 ± 491.6

minutes per week. These results indicate that the IPAQ-SF, PAVS, and logbook may all be used to determine moderate-to-vigorous physical activity levels of OSA patients; however, the PAVS will provide the most precise estimations.

The results of aim 1 provide strong support that the PAVS may be the more valid of the two questionnaires for examining moderate and moderate-to-vigorous physical activity levels within an overweight and sedentary OSA population. These results are somewhat counterintuitive because the PAVS is a less descriptive questionnaire than the IPAQ-SF; however, the IPAQ-SF significantly over predicts all physical activity types when compared to the PAVS.

The IPAQ-SF over predicting physical activity levels is not unique to the current study. Numerous studies have provided evidence that the IPAQ-SF tends to over-predict physical activity (Dinger et al., 2006; Grimm et al., 2012; Igelstrom et al., 2013). A study by Igelstrom and colleagues (2013) examined the validity of the IPAQ-SF within the OSA population and found that the IPAQ-SF over predicted moderate-to-vigorous physical activity by over five hours per week, which is very similar to the current study.

In considering possibilities for why the IPAQ-SF tends to over-predict physical activity levels, it is possible that the wording does not produce correct physical activity intensity interpretations by OSA patients. This assertion is made by examining the results of the PAVS, which was taken almost simultaneously with the IPAQ-SF and produced drastically lower physical activity level estimations. The wording of the IPAQ-SF should be examined to determine if it is in fact that reason for significant over predictions.

Another possibility for why the IPAQ-SF significantly over predicts physical activity levels may be its organization. The IPAQ-SF requires participants to determine

moderate and vigorous physical activity separately while the PAVS requires participants to think about total physical activity levels as a whole before stratifying them into moderate and vigorous. It is possible that this organization causes participants to double list physical activity. On more than one occasion during the study, participants expressed that they had listed physical activity in incorrect sections after reading the entire questionnaire. Despite making these comments, some participants did not erase what they had written previously. Future research should examine if reading the entire IPAQ-SF prior to completing it reduces over prediction of physical activity levels.

The previous two assertions are further supported when analyzing the results from the logbook. The participant's direct personal interpretation of physical activity over predicted moderate-to-vigorous physical activity levels by 191.2 minutes a week, which is similar to the IPAQ-SF which over predicted moderate-to-vigorous physical activity by 345.8 minutes a week. This provides further evidence that OSA patients, particularly those who are overweight or obese and have moderate to severe OSA may not have a strong comprehension of what moderate to vigorous physical activity entails.

Making a direct minute by minute comparison of the validity of the present study to previous research is difficult due to recent changes in Physical Activity Guidelines for Americans (Piercy et al., 2018). Previously, recommendations were that moderate-to-vigorous physical activity only count towards total weekly activity if done in at least 10-minute bouts (Piercy et al., 2018). This recommendation changed in 2018 to allow for all bouts of activity, regardless of the length, to count towards total weekly physical activity (Piercy et al., 2018). Most research prior to 2018 examining the validity of the IPAQ-SF, PAVS, or logbooks abided by the previous guidelines and included moderate-to-vigorous

physical activity from accelerometry only if it met the criteria of being done in 10-minute bouts or more (Ball et al., 2012; Dinger et al., 2006; Hagstromer et al., 2006; Igelstrom et al., 2013). Considering the new recommendations, the current study included all moderate-to-vigorous physical activity regardless of bout length. This makes a direct minute by minute comparison of previous validity research to the current study impossible.

Reliability

In order to determine test retest reliability, the results from the IPAQ-SF and PAVS from the first visit were compared to the results from the second visit, which occurred seven days later. The analyses were done using intraclass correlation coefficients.

With regard to the IPAQ-SF, reliability for vigorous and moderate-to-vigorous physical activity was good with estimations increasing by 3.1 ± 246 and 109.2 ± 627.8 minutes per week from the first to the second visit, respectively. Reliability for moderate physical activity was poor with estimations increasing by 106.2 ± 527 minutes per week from the first to the second visit. These results are similar to previous studies which have examined the IPAQ-SF and found it to have moderate to good reliability (Craig et al., 2002; Dinger et al., 2006; Hallal et al. 2004). Similar to the findings of the current study, a study by Dinger and colleagues (2006) found that the IPAQ-SF is moderately (0.71) reliable for moderate-to-vigorous physical activity and produces increases in estimations of moderate and vigorous physical activity the second time it is taken. It is difficult to ascertain why the IPAQ-SF caused increased physical activity estimations during the

second visit. Future research should investigate this phenomenon further within the OSA population.

With regard the PAVS, reliability for vigorous physical activity was excellent and estimations decreased by 23.8 ± 115.2 minutes per week from the first to the second visit. Reliability for moderate physical activity was also excellent and estimations increased by 14.1 ± 89.3 minutes per week from the first to the second visit. Lastly, reliability for moderate-to-vigorous physical activity was also excellent and estimations decreased by 8.6 ± 100.3 minutes per week from the first to the second visit. Since the PAVS is a relatively new physical activity questionnaire, few studies have examined its reliability. We have identified three studies that found the PAVS to have good to excellent reliability (Ball et al., 2012; Fowles et al., 2017). A study by Fowles and colleagues (2017) found the PAVS to have good reliability (.83) for moderate-to-vigorous physical activity when examined two times within an overweight and sedentary population.

The results indicate that the degree of reliability varies significantly between the IPAQ-SF and PAVS. The IPAQ-SF can be assumed to produce at least good reliability for vigorous and moderate-to-vigorous physical activity while the PAVS can be expected to produce excellent reliability for all physical activity types. The IPAQ-SF provides many different examples of activities that constitute moderate-to-vigorous intensity, while PAVS provides only one example for each. It is possible that many different and potentially conflated examples of types of activities by the IPAQ-SF produces differing results from one time to the next, whereas one example for each type of activity provided by the PAVS produces similar results.

Construct Validity

In order to determine construct validity of the IPAQ-SF, PAVS, and logbook, the results of each were compared to factors related to OSA such as OSA severity, quality of life, BMI, sleepiness, and CPAP adherence. This comparison was made using Spearman correlation coefficients.

With regard to the IPAQ-SF, significant relationships were found between BMI and moderate physical activity ($\rho = -.268$) as well as moderate-to-vigorous physical activity ($\rho = -.279$). These results are similar to previous research, which has examined the relationship between the IPAQ-SF and BMI (Hagstromer et al., 2006). A study similar to the current study by Hagstromer and colleagues (2006) recruited 46 adults and examined the relationship between the IPAQ-SF and BMI and found almost identical results in that significant relationships existed between moderate and moderate-to-vigorous physical activity and BMI but held low effect sizes in $\rho = -0.27$ and $\rho = -0.25$, respectively.

The PAVS was similar to the IPAQ-SF in that it only held significant relationships with BMI for moderate-to-vigorous physical activity ($\rho = -0.273$) and vigorous ($\rho = -0.331$) physical activity. These results are similar to a large population study, which examined 34,712 patients within a hospital system and found a significant relationship between the results of the PAVS and BMI (Ball et al., 2012).

The physical activity logbook was identical to the IPAQ-SF and PAVS in that it did not hold relationships with factors related to OSA other than with BMI. The logbook held significant relationships with moderate-to-vigorous physical activity ($\rho = -0.343$)

and BMI. To the author's knowledge, no previous study has examined construct validity of a physical activity logbook and BMI.

A relationship between physical activity estimation and BMI is to be expected as the relationship between physical activity and BMI has been well document by numerous studies over the previous decades (Piercy et al., 2018). Interestingly, the current study found that the IPAQ-SF, PAVS, and logbook held no relationship with factors related to OSA such as OSA severity, quality of life, sleepiness, and CPAP adherence. There are many possibilities as to why no relationship was found between these variables.

The study hypothesized that there would be an inverse relationship between the amount of estimated physical activity and OSA severity. Studies have demonstrated that when people gain weight, the likelihood of developing OSA increases, and when excess body weight is lost, the severity of OSA tends to decrease (Coughlin et al., 2004; Quan et al., 2007; Redline et al., 2003; young et al., 1993; Strohl & Redline, 1996). Considering these facts, we assumed that those who were more physically active would have less severe OSA, however, this relationship was not found.

The study hypothesized that there would a linear relationship between physical activity levels and the quality of life of the participants. Previous research has demonstrated that those with OSA are at higher risk for depression and typically have many comorbidities such as hypertension, diabetes, high cholesterol, heart disease, and obesity (Peppard et al., 2000; Peker et al., 2006; Punjabi & Polotsky, 2006). A physically active lifestyle has been demonstrated to improve many of these health issues (Giebelhaus et al. 2000; Ueno et al., 2009; Kline et al., 2011; Sengul et al., 2011). Due to

these facts, we believed that participants who were more physically active would have a higher quality of life, however, no relationship was found.

The study hypothesized that there would be a linear relationship between physical activity levels and CPAP adherence. No previous research has specifically examined this relationship but we believed there might be a relationship because those who are more physically active tend to be more disciplined which may make them more likely to adhere to CPAP (Duckworth et al., 2010). Ultimately, no relationship was found between physical activity levels and CPAP adherence.

The study hypothesized that there would be an inverse relationship between physical activity levels and sleepiness. Previous research has demonstrated that as OSA severity increases, so does sleepiness (Seneviratne and Puvanendran, 2004). This relationship makes sense because more severe OSA typically translates into more arousals from sleep and lower blood oxygen saturation. These side effects experienced in more severe OSA typically result in patients experiencing poorer quality sleep and more sleepiness during the day (Eckert & Malhotra, 2008; Seneviratne and Puvanendran, 2004). We hypothesized that there might be a relationship between physical activity levels and sleepiness because people with higher BMIs tend to have more severe OSA which tends to produce higher sleepiness scores (Seneviratne and Puvanendran, 2004). Previous research has also demonstrated a relationship between lower physical activity levels and increased sleepiness scores within the OSA population (Basta et al., 2008). Despite our rationale and previous research supporting the hypothesis, no relationship was found between physical activity levels and sleepiness.

Many possibilities may account for why no relationship was found between physical activity and sleepiness in the recruited population. One possibility may be directly related to another finding in the study which was that there is no relationship between physical activity and CPAP adherence. This finding demonstrates that increased physical activity levels do not translate into greater adherence to CPAP within an overweight and obese OSA population. It has been previously demonstrated that as patients become more adherent to CPAP, their sleepiness levels decrease (Antic et al., 2011). If the results of the current study are accurate and more physically active patients do not adhere better to CPAP then it cannot be expected that an overweight and obese OSA population will have lower sleepiness scores.

Exploratory

In order to determine if there was a relationship between objective physical activity levels as measured by the ActiGraph and factors related to OSA, the results from the ActiGraph were compared to OSA severity, quality of life, BMI, sleepiness, and CPAP adherence. This comparison was made using Spearman correlation coefficients. The results demonstrated that objective physical activity levels did not hold significant relationships with OSA severity, quality of life, sleepiness, or CPAP adherence. The only relationship that objective physical activity levels held was with BMI.

The significant relationships found were between objective moderate-to-vigorous physical activity ($\rho = -0.320$) and objective moderate physical activity ($\rho = -0.335$). These results are in line with previous studies which have examined objective physical activity and BMI (Hagstromer et al., 2007). A large population study by Hagstromer and colleagues (2007) recruited 1114 adults and tracked physical activity of participants using

accelerometry for seven consecutive days. The study found a significant relationship between lower moderate-to-vigorous physical activity levels and higher BMI scores.

Limitations

Limitations exist within the study. In terms of recruitment, diagnosis of participants took place at different clinics by different interpreting doctors during different points in time. It is possible that varying degrees of severity were diagnosed in participants solely due to the fact that diagnosis occurred at different clinics, which use different systems and have different interpreting doctors. Obstructive sleep apnea severity may also have changed over time since diagnosis in some participants occurred years prior to study. Both of these factors may have influenced the results, especially with regard to construct validity of the IPAQ-SF, PAVS, logbook, and objective physical activity levels. If the study were to have taken place at one clinic, where one interpreting doctor diagnosed all participants at a similar point in time, different results may have observed.

In terms of the population recruited, the current study focused on an overweight and obese OSA population with moderate to severe OSA and low levels of physical activity. For this reason, it is possible that other OSA populations, such as those who are of a normal weight or are more physically active, may have produced different results.

In terms of physical activity, a limitation may be due to the period of time in which the study took place. The study began in the spring and was completed at the beginning of the summer. A study by Tucker and Gilliland (2007) found that the spring and summer months are when people tend to more physically active. If the study was

done during a different season or throughout the course of an entire year, it is possible that different results for objective physical activity would have been found.

Future Implications

The study found differences in the validity and reliability of the three questionnaires. Both the IPAQ-SF and physical activity logbook held moderate validity and reliability for determining moderate-to-vigorous physical activity, while the PAVS held excellent validity and reliability for determining both moderate and moderate-to-vigorous physical activity. These results indicate that while the IPAQ-SF, PAVS, or logbook would all be reasonable options for determining moderate-to-vigorous physical activity, the PAVS is the best choice for precisely determining physical activity levels within the OSA patients who participated in this study.

As noted in chapter II, despite the fact that physical activity questionnaires are commonly used within clinical practice and in research, no questionnaire has been validated within the OSA population. The study was unique in the fact that it addressed this issue and now provides initial evidence that supports a reliable and valid questionnaire for clinicians and researchers to utilize in the future with individuals who suffer from OSA. By providing a valid, inexpensive, and time efficient tool for the determination of moderate-to-vigorous physical activity levels, clinicians will be able to better serve their OSA patients by having a more complete understanding of their overall physical health. This will allow for more appropriate and catered treatment of their OSA, as well as a means to determine the effectiveness of protocols aimed at increasing physical activity levels. The questionnaire will also allow researchers to better study and understand the relationships between physical activity levels and factors related to OSA.

Future Directions

There are many avenues for future research with regard to physical activity questionnaires. Large population studies should be done using the PAVS to better understand the relationship between OSA and moderate to vigorous physical activity levels. It is well documented that increased physical activity is beneficial for decreasing the severity of OSA on an individual level, but how specific physical activity levels relate to OSA as a whole is an area that needs further exploration (Giebelhaus et al. 2000; Ueno et al., 2009; Kline et al., 2011; Sengul et al., 2011). While the current study attempted to address this, the sample size was small and limitations were present. This information would provide clinicians with a means to tailor physical activity recommendations and it would provide researchers with a better idea of what types of physical activity interventions to examine.

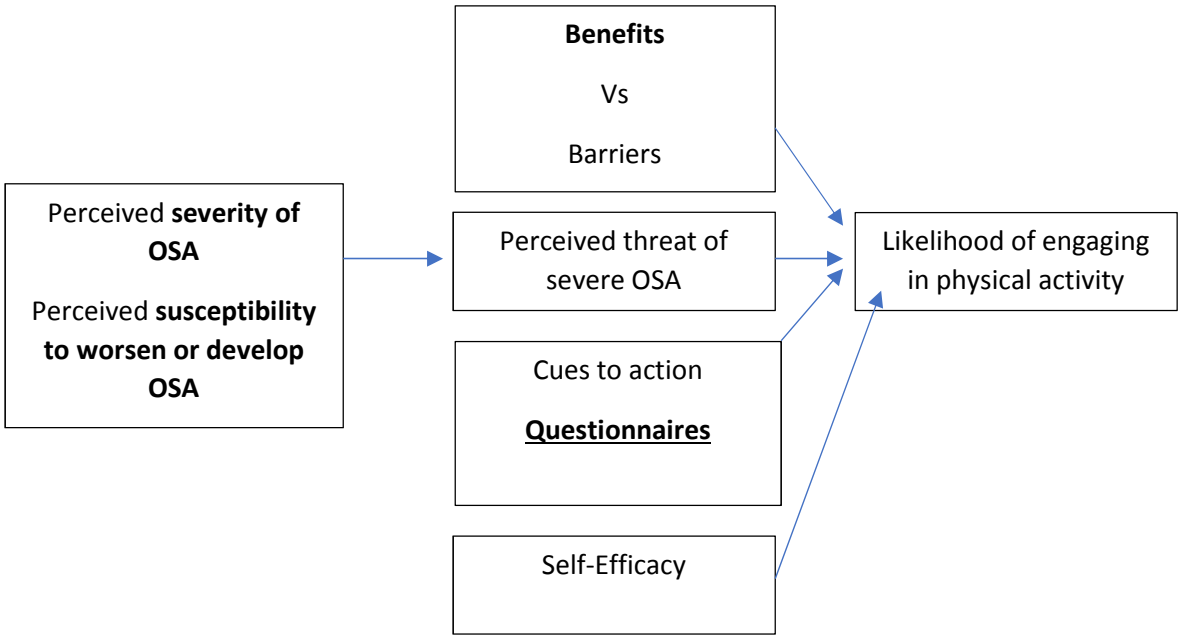
Future research should also examine the utility of the questionnaires for increasing physical activity within OSA patients or patients at risk for developing OSA. One of the best models for predicting whether people will engage in activities that are beneficial for their health, or in this case physical activity, is the Health Belief Model (Janz and Becker, 1984). One major construct of the Health Belief Model is that people must have a perceived threat in order to take action. In the case of OSA, this would involve patients understanding the serious threat to overall health that OSA presents as well as what makes them susceptible to developing OSA. Increasing awareness of these facts would involve counseling of patients by researchers or clinicians.

After a perceived threat for a health disorder is established, the Health Belief Model states that individuals must understand the benefits of engaging in activities that

will decrease the likeness of developing or worsening of a health disorder. With regard to physical activity and OSA, this would involve informing OSA patients about how physical activity is capable of reducing the chance of developing or worsening existing OSA. Similar to perceived threat, counseling by clinicians or researchers would need to be applied in order for OSA patients to understand the benefits of physical activity.

Lastly, and most importantly with regard to the current study, the Health Belief Model states that there must be a cue to action (Janz and Becker, 1984). As discussed previously, patients must understand that they are susceptible to OSA and it has serious health consequences. They must also understand that engaging in physical activity reduces the likelihood of developing or worsening OSA, but they also must have a cue to action otherwise they are not likely to engage in physical activity (Janz and Becker, 1984). A validated physical activity questionnaire such as the PAVS would allow OSA patients to get an immediate understanding of their current physical activity levels and this may serve as a que to action and increase the likeness of OSA patients engaging in physical activity. Whether or not the PAVS can used within this model to increase physical activity levels of OSA patients should be explored. A schematic of how the PAVS may be integrated within the Health Belief Model is found in figure 7.

Figure 7. Utilization of the PAVS within the Health Belief Model



Appendices

Appendix 1: Recruitment Flyer

Are Physical Activity Questionnaires Valid in Patients with Obstructive Sleep Apnea?

Obstructive sleep apnea (OSA) is a highly prevalent, yet frequently undiagnosed sleep disorder. Evidence continues to mount linking OSA to numerous health concerns, including diabetes, high blood pressure, heart attack, and stroke. Research has demonstrated that increased physical activity and exercise may be a novel treatment for decreasing the severity of OSA, although the relationship between physical activity levels and OSA remains poorly understood.

Research Study

Researchers at the IUPUI Departments of Kinesiology are conducting a research study to determine whether a physical activity questionnaire is accurate within the OSA population. If you are a male or female (age 18-65) and have been diagnosed with moderate-severe OSA and are not currently being treated with or actively using CPAP, you may qualify for this research study.

The study consists of wearing a hip-worn activity tracker for seven days and answering three physical activity questionnaires before, and again after, the seven days of activity tracking.

For additional information about this study, please contact Max Adolphs by email at madolphs@iu.edu.

Appendix 2: Email Script

THE VALIDITY AND RELIABILITY OF THE PAVS AND IPAQ AS PHYSICAL ACTIVITY ASSESSMENT TOOLS IN PATIENTS WITH OBSTRUCTIVE SLEEP APNEA

The IUPUI Department of Kinesiology is seeking volunteers to participate in a study to evaluate the accuracy of physical activity questionnaires in individuals diagnosed with Obstructive Sleep Apnea (OSA). If you are between 18 and 65 years of age, have a diagnosis of moderate-severe OSA, and are not currently being treated with or actively using continuous positive airway pressure, you may qualify for the study. For additional information, contact Max Adolphs at madolphs@iu.edu.

Appendix 3: All IN for Health Registry Email

Dear <<Contact name>>,

Thank you for your participation in All IN for Health's Volunteer Registry!

We are contacting you because you may be interested in participating in a study being conducted by the IUPUI School of Health and Human Sciences. The study, called **The Validity and Reliability of the PAVS and IPAQ-SF as Physical Activity Assessment Tools in Patients with Obstructive Sleep Apnea**, wants to determine whether two physical activity questionnaires are reliable and valid within the Obstructive sleep apnea (OSA) population.

In order to participate in the study, you must:

a. be 18-65 years of age
b. diagnosed with obstructive sleep apnea

If you are eligible, and you decide to participate, you will be asked to meet with someone from the study team at a convenient location. **Specifically, you will be asked to wear a hip-worn activity tracker for seven days and answer two physical activity questionnaires before, and again after, the seven days of activity tracking.** For your time, you will be compensated with Visa gift cards: $50 after completion of the first visit and another $100 after completion of the second visit.

If you have any questions or would just like more information, please contact Max Adolphs by email at madolphs@iu.edu.

Thank you for your time and continued interest and support of our research.

Warm regards,

The All IN for Health Team

www.allin4health.info

chat@allin4health.info

1-888-264-0005

Appendix 4: IPAQ-SF

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ days per week

   ☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ hours per day
   _____ minutes per day

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   _____ days per week

   ☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**
_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ days per week

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**
_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**
_____ **minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

Appendix 5: PAVS

1. Please describe your level of physical activity:

Minutes each day: _____

Number of days each week: _____

2. At what intensity (how hard):

Light (like a casual walk)
Moderate (like a brisk walk)
Vigorous (like a jog/run)

Appendix 6: Epworth Sleepiness Scale

Epworth sleepiness scale

How likely are you to doze off or fall asleep during the following situations,
in contrast to just feeling tired?

For each of the situations listed below, give yourself a score of 0 to 3, where
0 = Would never doze; 1 = Slight chance; 2 = Moderate chance; 3 = High chance.

Work out your total score by adding up your individual scores for situations 1 to 8. (If you have not been in the following situations recently, think about how you would have been affected.)

Situation	Score
Sitting and reading	
Watching television	
Sitting inactive in a public place (e.g. a theatre/meeting)	
As a passenger in a car for an hour with no break	
Lying down in the afternoon (when possible)	
Sitting and talking to someone	
Sitting quietly after lunch without alcohol	
In a car, while stopped for a few minutes in traffic	
Total	

Appendix 7: Quality of Life Questionnaire

1. **Would you say that in general your health is; Excellent, Very good, Good, Fair or Poor?**

2. **Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good?**

3. **Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?**

4. **During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?**

Appendix 8: Cognitive Impairment Questionnaire

Now some of these questions may seem easy and some may seem hard. Please answer each question the best you can.

QUESTION	RECORD PATIENT'S RESPONSE	CORRECT RESPONSE	SCORE
1. What is the date today?		Exact month, exact date, exact year	0 / 1
2. What day of the week is it?		Exact day of the week	0 / 1
3. What is the name of this place?		Doctor's Office OR Medical Clinic OR Indianapolis OR Wishard Hospital OR IU Medical Group OR Primary Care Clinic	0 / 1
4. What is your telephone number? (If no phone, ask question 4.A. below)	*	Insert from appt. list:	0 / 1
4.A. What is your address?	*	Insert from appt. list:	0 / 1
5. How old are you?		Must correspond with year of birth given in #6 below.	0 / 1
6. When were you born?	*	Must be exact month, date, and year Insert from appt. list:	0 / 1
7. Who is the President of the U.S. now?		Bush	0 / 1
8. Who was President just before him?		Clinton	0 / 1
9. What was your mother's maiden name?		Any female first and last name (last name other than patient's)	0 / 1
10. Subtract 3 from 20 and keep subtracting 3 from each new number, all the way down.		20, 17, 14, 11, 8, 5, 2	0 / 1
* 11. If patient's response to any of these items does not match data on appt. list, after Question 10 repeat the item and record response here. Phone #:_____ Address:_____ DOB: If patient's response matches their original response given above, score item as correct. If patient's response does not match their original response, score item as incorrect.		Add scores for items 1-10	
		If patient has only grade school (6) education, add 1 (score cannot exceed "10")	
		If patient is African American, add 1 (score cannot exceed "10")	

Appendix 9: Informed Consent

INDIANA UNIVERSITY INFORMED CONSENT STATEMENT FOR

The Validity and Reliability of the PAVS and IPAQ-SF as Physical Activity Assessment Tools in Patients with Obstructive Sleep Apnea

You are invited to participate in a research study determining the validity and reliability of two physical activity questionnaires within the obstructive sleep apnea population. You were selected as a possible subject because you are male or female, between the ages of 18-65 years old and have been diagnosed with moderate to severe obstructive sleep apnea (OSA). Please read this form and ask any questions you may have before agreeing to be in the study.

The study is being conducted by Max Adolphs, Indiana University-Purdue University-Indianapolis, School of Health and Human Sciences and Anthony Kaleth Indiana University-Purdue University- Indianapolis, School of Health and Human Sciences

STUDY PURPOSE

The purpose of this study is to see if scientists can use the International Physical Activity Questionnaire Short Form (IPAQ-SF) and Physical Activity Vital Sign (PAVS) questionnaire in the OSA population to accurately see how physically active people are.

NUMBER OF PEOPLE TAKING PART IN THE STUDY

If you agree to participate, you will be one of 50 subjects who will be participating in this research.

PROCEDURES FOR THE STUDY

If you agree to be in the study, you will do the following things:

During the **first visit**, which is taking place here today, you will be asked to:

- You will first complete an authorization form that will allow the research team to access your medical records.
- You will then complete the IPAQ-SF and PAVS, which are both short questionnaires that will ask you questions about how much physical activity you have done over the past week as well as the intensity of the physical activity.
- You will also complete a cognitive impairment and quality of life questionnaire.
    - The cognitive impairment questionnaire will ask very straightforward questions such as your age and answers to addition and subtraction math questions.
    - The quality of life questionnaire will ask you to rate your level of health.
- You will then be fitted with a belt around the waist that will serve as the attachment point for the ActiGraph. The ActiGraph is an activity tracker that will record the amount of physical activity you do over the course of the next week. You will keep the Actigraph in a pouch, which exists on the belt on top of your right hip. You will need make sure the Velcro flap is pointed downward and away from your body.

- You will wear the Actigraph during all waking hours for the next seven consecutive days, except when showering, bathing, or swimming. You will remove the Actigraph when going to bed at night and record what time you put on and removed the Actigraph each day onto a log sheet.
- You will record the amount and intensity of physical activity you do over the course of the week on a log sheet
- You will record how much you use your CPAP each night on a log sheet

Second visit. Following the seven days, you will meet with a researcher a second time at a mutually agreed upon location to return the Actigraph and complete the IPAQ and PAVS a second time.

RISKS OF TAKING PART IN THE STUDY
While on the study, the potential risks (side effects and/or discomforts) are:
Risks associated with this study are minimal. You are being asked to live normally with no increases or decreases in physical activity levels other than those typically performed during a normal week.

If you feel uncomfortable answering any of the questions, then you do not need to answer. In that case, please skip the question and answer the next.
There is a small risk of loss of confidentiality.

BENEFITS OF TAKING PART IN THE STUDY
There are no direct benefits to participation but we hope that your data will contribute valuable information regarding the accuracy of the PAVS and IPAQ as physical activity assessment tools within the OSA population.

ALTERNATIVES TO TAKING PART IN THE STUDY
Participation in this study is voluntary and there are no alternative treatments or procedures that might be advantageous to you, should you choose not to participate in this study.

CONFIDENTIALITY
Efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Your identity will be held in confidence in reports in which the study may be published and databases in which results may be stored

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board or its designees, the study sponsor and (as allowed by law) state or federal agencies, specifically the Office for Human Research Protections (OHRP) who may access your research records.

USE OF YOUR INFORMATION IN FUTURE RESEARCH
Information collected from you for this study may be used for future research studies or shared with other researchers for future research. If this happens, information which could identify you will be removed before any information is shared. Since identifying information will be removed, we will not ask for your additional consent.

COSTS
There are no additional costs related to participating in this study. Expenses that result from transportation to a mutually agreed upon location will be your responsibility.

PAYMENT
You will receive payment for taking part in this study. At the completion of the first visit, you will receive $50 in the form of a Visa gift card, which can be used for purchases at any location which accepts Visa. By completing both sessions, you will receive another $100 in the form of a Visa gift card.

CONTACTS FOR QUESTIONS OR PROBLEMS
For questions about the study during and after business hours, contact the researcher, Max Adolphs.
In the event of an emergency, you may contact Max Adolphs
For questions about your rights as a research participant, to discuss problems, complaints, or concerns about a research study, or to obtain information or offer input, contact the IU Human Subjects Office at 800-696-2949 or irb@iu.edu.

VOLUNTARY NATURE OF THIS STUDY
Taking part in this study is voluntary. You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. Your decision whether or not to participate in this study will not affect your current or future relations with Indiana University Purdue University Indianapolis.

SUBJECT'S CONSENT
In consideration of all of the above, I give my consent to participate in this research study.

I will be given a copy of this informed consent document to keep for my records. I agree to take part in this study.

Subject's Printed Name:_____
Subject's Signature:_____
Date:_____
(must be dated by the subject)

Printed Name of Person Obtaining Consent:_____

Signature of Person Obtaining Consent:_____
Date:_____

References

Ainsworth, B. E. (2009). How do I measure physical activity in my patients? Questionnaires and objective methods. *British Journal of Sports Medicine*, *43*(1), 6–9.

Ainsworth, B. E., Haskell, W. L., Leon, A. S., Jacobs, J. D., Montoye, H. J., Sallis, J. F., & Paffenbarger, J. R. (1993). Compendium of physical activities: classification of energy costs of human physical activities. *Medicine and Science in Sports and Exercise*, *25*(1), 71–80.

Al-Delaimy, W. K., Manson, J. E., Willett, W. C., Stampfer, M. J., & Hu, F. B. (2002). Snoring as a risk factor for type II diabetes mellitus: a prospective study. *American Journal of Epidemiology*, *155*(5), 387–393

American College of Sports Medicine. (2013). ACSM's guidelines for exercise testing and prescription.Lippincott Williams & Wilkins.

American Psychological Association. (2015). APA Dictionary of Psychology. American Psychological Association.

Antic, N. A., Catcheside, P., Buchan, C., Hensley, M., Naughton, M. T., Rowland, S., … McEvoy, R. D. (2011). The Effect of CPAP in Normalizing Daytime Sleepiness, Quality of Life, and Neurocognitive Function in Patients with Moderate to Severe OSA. *Sleep*, *34*(1), 111–119.

Arzt, M., Young, T., Finn, L., Skatrud, J. B., & Bradley, T. D. (2005). Association of sleep-disordered breathing and the occurrence of stroke. *American Journal of Respiratory and Critical Care Medicine*, *172*(11), 1447–1451.

Austin, M., Breslow, J., Hennekens, C., Buring, J., Willett, W., & Krauss, R. (1988). Low-Density Lipoprotein Subclass Patterns and Risk of Myocardial-Infarction. *Jama-Journal of the American Medical Association*, *260*(13), 1917–1921.

Ball, T. J., Joy, E. A., Gren, L. H., Cunningham, R., & Shaw, J. M. (2016). Predictive Validity of an Adult Physical Activity "Vital Sign" Recorded in Electronic Health Records. *Journal of Physical Activity and Health*, *13*(4), 403–408.

Ball, T. J., Joy, E. A., Goh, T. L., Hannon, J. C., Gren, L. H., & Shaw, J. M. (2015). Validity of two brief primary care physical activity questionnaires with accelerometry in clinic staff. *Primary Health Care Research & Development*, *16*(1), 100–108.

Ball, T. J., Joy, E. A., Gren, L. H., & Shaw, J. M. (2016). Concurrent Validity of a Self-Reported Physical Activity "Vital Sign" Questionnaire With Adult Primary Care Patients. *Preventing Chronic Disease*, *13*.

Ballor, D. L., & Keesey, R. E. (1991). A meta-analysis of the factors affecting exercise-induced changes in body mass, fat mass and fat-free mass in males and females. *International Journal of Obesity*, *15*(11), 717–726.

Bamberga, M., Rizzi, M., Gadaleta, F., Grechi, A., Baiardini, R., & Fanfulla, F. (2015). Relationship between energy expenditure, physical activity and weight loss during CPAP treatment in obese OSA subjects. *Respiratory Medicine*, *109*(4), 540–545.

Bartko, J. J. (1976). On various intraclass correlation reliability coefficients. *Psychological Bulletin*, *83*(5), 762–765.

Barvaux, V., Aubert, G., & Rodenstein, D. (2000). CLINICAL REVIEW ARTICLE: Weight loss as a treatment for obstructive sleep apnoea. *Sleep Medicine Reviews*, *4*(5), 435–452.

Basset FA (2008) Fighting the obesity epidemic. *Down Home* 44th edition. 72-73

Basta, M., Lin, H.-M., Pejovic, S., Sarrigiannidis, A., Bixler, E. O., & Vgontzas, A. N. (2008). Lack of Regular Exercise, Depression, and Degree of Apnea are Predictors of Excessive Daytime Sleepiness in Patients with Sleep Apnea: Sex Differences. *Journal of Clinical Sleep Medicine : JCSM : Official Publication of the American Academy of Sleep Medicine*, *4*(1), 19–25.

Batool-Anwar, S., Goodwin, J. L., Drescher, A. A., Baldwin, C. M., Simon, R. D., Smith, T. W., & Quan, S. F. (2014). Impact of CPAP on Activity Patterns and Diet in Patients with Obstructive Sleep Apnea (OSA). *Journal of Clinical Sleep Medicine*, *10*(05), 465–472.

Bazzano, L. A., Khan, Z., Reynolds, K., & He, J. (2007). Effect of nocturnal nasal continuous positive airway pressure on blood pressure in obstructive sleep apnea. *Hypertension (Dallas, Tex.: 1979)*, *50*(2), 417–423.

Becker, H. F., Jerrentrup, A., Ploch, T., Grote, L., Penzel, T., Sullivan, C. E., & Peter, J. H. (2003). Effect of nasal continuous positive airway pressure treatment on blood pressure in patients with obstructive sleep apnea. *Circulation*, *107*(1), 68–73.

Bédard, M. A., Montplaisir, J., Malo, J., Richer, F., & Rouleau, I. (1993). Persistent neuropsychological deficits and vigilance impairment in sleep apnea syndrome after treatment with continuous positive airways pressure (CPAP). *Journal of Clinical and Experimental Neuropsychology*, *15*(2), 330–341.

Bittner, V., Weiner, D. H., Yusuf, S., Rogers, W. J., McIntyre, K. M., Bangdiwala, S. I., … Bourassa, M. G. (1993). Prediction of Mortality and Morbidity With a 6-Minute Walk Test in Patients With Left Ventricular Dysfunction. *JAMA*, *270*(14), 1702–1707.

Bixler, E. O., Vgontzas, A. N., Ten Have, T., Tyson, K., & Kales, A. (1998). Effects of age on sleep apnea in men: I. Prevalence and severity. *American Journal of Respiratory and Critical Care Medicine*, *157*(1), 144–148.

Bixler, E. O., Vgontzas, A. N., Lin, H. M., Ten Have, T., Rein, J., Vela-Bueno, A., & Kales, A. (2001). Prevalence of sleep-disordered breathing in women: effects of gender. *American Journal of Respiratory and Critical Care Medicine*, *163*(3 Pt 1), 608–613.

Black, H. R. (2003). The burden of cardiovascular disease: following the link from hypertension to myocardial infarction and heart failure. *American Journal of Hypertension*, *16*(S2), 4S–6S.

Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet (London, England)*, *1*(8476), 307–310.

Boyd, J. H., Petrof, B. J., Hamid, Q., Fraser, R., & Kimoff, R. J. (2004). Upper airway muscle inflammation and denervation changes in obstructive sleep apnea. *American Journal of Respiratory and Critical Care Medicine*, *170*(5), 541–546.

Brooks, D., Horner, R. L., Kozar, L. F., Render-Teixeira, C. L., & Phillipson, E. A. (1997). Obstructive sleep apnea as a cause of systemic hypertension. Evidence from a canine model. *Journal of Clinical Investigation*, *99*(1), 106–109.

Buchowski, M. S., Townsend, K. M., Chen, K. Y., Acra, S. A., & Sun, M. (1999). Energy expenditure determined by self-reported physical activity is related to body fatness. *Obesity Research*, *7*(1), 23–33.

Carlson, J. T., Hedner, J. A., Sellgren, J., Elam, M., & Wallin, B. G. (1996). Depressed baroreflex sensitivity in patients with obstructive sleep apnea. *American Journal of Respiratory and Critical Care Medicine*, *154*(5), 1490–1496.

Chervin, R. D., Archbold, K. H., Dillon, J. E., Panahi, P., Pituch, K. J., Dahl, R. E., & Guilleminault, C. (2002). Inattention, hyperactivity, and symptoms of sleep-disordered breathing. *Pediatrics*, *109*(3), 449–456.

Coleman, K. J., Ngor, E., Reynolds, K., Quinn, V. P., Koebnick, C., Young, D. R., Sallis, R. E. (2012). Initial validation of an exercise "vital sign" in electronic medical records. *Medicine and Science in Sports and Exercise*, *44*(11), 2071–2076.

Cossrow, N., & Falkner, B. (2004). Race/Ethnic Issues in Obesity and Obesity-Related Comorbidities. *The Journal of Clinical Endocrinology & Metabolism*, *89*(6), 2590–2594.

Coughlin, S. R., Mawdsley, L., Mugarza, J. A., Calverley, P. M. A., & Wilding, J. P. H. (2004). Obstructive sleep apnoea is independently associated with an increased prevalence of metabolic syndrome. *European Heart Journal*, *25*(9), 735–741.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise*, *35*(8), 1381–1395.

Craig, C. L., Marshall, A. L., Sj??Str??M, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., … Oja, P. (2003). International Physical Activity Questionnaire: 12-Country Reliability and Validity: *Medicine & Science in Sports & Exercise*, *35*(8), 1381–1395.

Dampney, R. a. L., Horiuchi, J., Killinger, S., Sheriff, M. J., Tan, P. S. P., & McDowall, L. M. (2005). Long-term regulation of arterial blood pressure by hypothalamic nuclei: some critical questions. *Clinical and Experimental Pharmacology & Physiology*, *32*(5–6), 419–425.

Diamanti, C., Manali, E., Ginieri-Coccossis, M., Vougas, K., Cholidou, K., Markozannes, E., … Alchanatis, M. (2013). Depression, physical activity, energy consumption, and quality of life in OSA patients before and after CPAP treatment. *Sleep and Breathing*, *17*(4), 1159–1168.

Dick, T. E., Hsieh, Y.-H., Wang, N., & Prabhakar, N. (2007). Acute intermittent hypoxia increases both phrenic and sympathetic nerve activities in the rat. *Experimental Physiology*, *92*(1), 87–97.

Douglas, J. G., Bakris, G. L., Epstein, M., Ferdinand, K. C., Ferrario, C., Flack, J. M., … Vidt, D. G. (2003). Management of High Blood Pressure in African Americans: Consensus Statement of the Hypertension in African Americans Working Group of the International Society on Hypertension in Blacks. *Archives of Internal Medicine*, *163*(5), 525–541.

Duckworth, A. L., Grant, H., Loew, B., Oettingen, G., & Gollwitzer, P. M. (2011). Self□regulation strategies improve self□discipline in adolescents: benefits of mental contrasting and implementation intentions. *Educational Psychology*, *31*(1), 17–26.

Durán, J., Esnaola, S., Rubio, R., & Iztueta, A. (2001). Obstructive sleep apnea-hypopnea and related clinical features in a population-based sample of subjects aged 30 to 70 yr. *American Journal of Respiratory and Critical Care Medicine*, *163*(3 Pt 1), 685–689.

Dyugovskaya, L., Lavie, P., & Lavie, L. (2002). Increased adhesion molecules expression and production of reactive oxygen species in leukocytes of sleep apnea patients. *American Journal of Respiratory and Critical Care Medicine*, *165*(7), 934–939.

Eckert, D. J., & Malhotra, A. (2008). Pathophysiology of Adult Obstructive Sleep Apnea. *Proceedings of the American Thoracic Society*, *5*(2), 144–153.

Ekelund, U., Sepp, H., Brage, S., Becker, W., Jakes, R., Hennings, M., & Wareham, N. J. (2006). Criterion-related validity of the last 7-day, short form of the International Physical Activity Questionnaire in Swedish adults. *Public Health Nutrition*, *9*(2), 258–265.

Fatureto-Borges, F., Lorenzi-Filho, G., & Drager, L. F. (2016). Effectiveness of continuous positive airway pressure in lowering blood pressure in patients with obstructive sleep apnea: a critical review of the literature. *Integrated Blood Pressure Control*, *9*, 43–47.

Fava, M. (2004). Daytime Sleepiness and Insomnia as Correlates of Depression. *The Journal of Clinical Psychiatry*, *65*(Suppl16), 27–32.

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. *Medicine and Science in Sports and Exercise*, *30*(5), 777–781.

Fernald, D. H., Froshaug, D. B., Dickinson, L. M., Balasubramanian, B. A., Dodoo, M. S., Holtrop, J. S., Green, L. A. (2008). Common measures, better outcomes (COMBO): a field test of brief health behavior measures in primary care. *American Journal of Preventive Medicine*, *35*(5 Suppl), S414-422.

Fogel, R. B., Malhotra, A., & White, D. P. (2004). Sleep. 2: pathophysiology of obstructive sleep apnoea/hypopnoea syndrome. *Thorax*, *59*(2), 159–163.

Fogel, R. B., Malhotra, A., & White, D. P. (2004). Sleep. 2: pathophysiology of obstructive sleep apnoea/hypopnoea syndrome. *Thorax*, *59*(2), 159–163.

Foley, D. J., Monjan, A. A., Brown, S. L., Simonsick, E. M., Wallace, R. B., & Blazer, D. G. (1995). Sleep complaints among elderly persons: an epidemiologic study of three communities. *Sleep*, *18*(6), 425–432.

Fowles, J. R., O'Brien, M. W., Wojcik, W. R., d'Entremont, L., & Shields, C. A. (2017). A pilot study: Validity and reliability of the CSEP−PATH PASB-Q and a new leisure time physical activity questionnaire to assess physical activity and sedentary behaviours. *Applied Physiology, Nutrition, and Metabolism*, *42*(6), 677–680.

Freedson P. S., Melanson E., Sirard J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. Med. Sci. Sports Exerc. 30, 777–781.

Gianotti, L., Pivetti, S., Lanfranco, F., Tassone, F., Navone, F., Vittori, E., Maccario, M. (2002). Concomitant impairment of growth hormone secretion and peripheral sensitivity in obese patients with obstructive sleep apnea syndrome. *The Journal of Clinical Endocrinology and Metabolism*, *87*(11), 5052–5057.

Giebelhaus, V., Strohl, K. P., Lormes, W., Lehmann, M., & Netzer, N. (2000). Physical Exercise as an Adjunct Therapy in Sleep Apnea—An Open Trial. *Sleep and Breathing*, *4*(4), 173–176.

Glasgow, R. E., Ory, M. G., Klesges, L. M., Cifuentes, M., Fernald, D. H., & Green, L. A. (2005). Practical and relevant self-report measures of patient health behaviors for primary care research. *Annals of Family Medicine*, *3*(1), 73–81.

Greenwood, J. L. J., Joy, E. A., & Stanford, J. B. (2010). The Physical Activity Vital Sign: a primary care tool to guide counseling for obesity. *Journal of Physical Activity & Health*, *7*(5), 571–576.

Grimm, E. K., Swartz, A. M., Hart, T., Miller, N. E., & Strath, S. J. (2012). Comparison of the IPAQ-Short Form and Accelerometry Predictions of Physical Activity in Older Adults. *Journal of Aging and Physical Activity*, *20*(1), 64–79.

Grunstein, R. R., Stenlöf, K., Hedner, J. A., Peltonen, M., Karason, K., & Sjöström, L. (2007). Two year reduction in sleep apnea symptoms and associated diabetes incidence after weight loss in severe obesity. *Sleep*, *30*(6), 703–710.

Hagströmer, M., Oja, P., & Sjöström, M. (2006). The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutrition*, *9*(6), 755–762.

Hagströmer, M., Oja, P., & Sjöström, M. (2007). Physical activity and inactivity in an adult population assessed by accelerometry. *Medicine and Science in Sports and Exercise*, *39*(9), 1502–1508.

Halbower, A. C., Degaonkar, M., Barker, P. B., Earley, C. J., Marcus, C. L., Smith, P. L., Mahone, E. M. (2006). Childhood obstructive sleep apnea associates with neuropsychological deficits and neuronal brain injury. *PLoS Medicine*, *3*(8), e301.

Hall, J. E. (2003). The Kidney, Hypertension, and Obesity. *Hypertension*, *41*(3), 625–633.

Härmä, M., Tenkanen, L., Sjöblom, T., Alikoski, T., & Heinsalmi, P. (1998). Combined effects of shift work and life-style on the prevalence of insomnia, sleep deprivation and daytime sleepiness. *Scandinavian Journal of Work, Environment & Health*, *24*(4), 300–307.

Haskell, W. L., Lee, I.-M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., Bauman, A. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*, *39*(8), 1423–1434.

Hendelman, D., Miller, K., Baggett, C., Debold, E., & Freedson, P. (2000). Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Medicine and Science in Sports and Exercise*, *32*(9 Suppl), S442-449.

Hiddink, G. J., Hautvast, J. G., van Woerkum, C. M., Fieren, C. J., & van 't Hof, M. A. (1997). Consumers' expectations about nutrition guidance: the importance of primary care physicians. *The American Journal of Clinical Nutrition*, *65*(6 Suppl), 1974S–1979S.

Hoffman, R. P., Sinkey, C. A., Dopp, J. M., & Phillips, B. G. (2002). Systemic and local adrenergic regulation of muscle glucose utilization during hypoglycemia in healthy subjects. *Diabetes*, *51*(3), 734–742.

Hojat, M., & Xu, G. (2004). A Visitor's Guide to Effect Sizes – Statistical Significance Versus Practical (Clinical) Importance of Research Findings. *Advances in Health Sciences Education*, *9*(3), 241–249

Ip, M. S. M., Lam, B., Ng, M. M. T., Lam, W. K., Tsang, K. W. T., & Lam, K. S. L. (2002). Obstructive sleep apnea is independently associated with insulin resistance. *American Journal of Respiratory and Critical Care Medicine*, *165*(5), 670–676.

Jean, R. E., Duttuluri, M., Gibson, C. D., Mir, S., Fuhrmann, K., Eden, E., & Supariwala, A. (2016). Improvement in Physical Activity in Persons With Obstructive Sleep Apnea Treated With Continuous Positive Airway Pressure. *Journal of Physical Activity and Health*, *14*(3), 176–182.

Johns, M. W. (1991). A New Method for Measuring Daytime Sleepiness: The Epworth Sleepiness Scale. *Sleep*, *14*(6), 540–545.

Jones, F., Harris, P., Waller, H., & Coggins, A. (2005). Adherence to an exercise prescription scheme: The role of expectations, self-efficacy, stage of change and psychological well-being. *British Journal of Health Psychology*, *10*(3), 359–378.

Karter, A. J., D'Agostino, R. B., Mayer-Davis, E. J., Wagenknecht, L. E., Hanley, A. J. G., Hamman, R. F., … IRAS investigators. (2005). Abdominal obesity predicts declining insulin sensitivity in non-obese normoglycaemics: the Insulin Resistance Atherosclerosis Study (IRAS). *Diabetes, Obesity & Metabolism*, *7*(3), 230–238.

Kline, C. E., Crowley, E. P., Ewing, G. B., Burch, J. B., Blair, S. N., Durstine, J. L., Youngstedt, S. D. (2011). The Effect of Exercise Training on Obstructive Sleep Apnea and Sleep Quality: A Randomized Controlled Trial. *Sleep*, *34*(12), 1631–1640.

Knauert, M., Naik, S., Gillespie, M. B., & Kryger, M. (2015). Clinical consequences and economic costs of untreated obstructive sleep apnea syndrome. *World Journal of Otorhinolaryngology - Head and Neck Surgery*, *1*(1), 17–27.

Kurtze, N., Rangul, V., & Hustvedt, B.-E. (2008). Reliability and validity of the international physical activity questionnaire in the Nord-Trøndelag health study (HUNT) population of men. *BMC Medical Research Methodology*, *8*, 63.

Lam, B., Ip, M. S. M., Tench, E., & Ryan, C. F. (2005). Craniofacial profile in Asian and white subjects with obstructive sleep apnoea. *Thorax*, *60*(6), 504–510.

Lang HF, Chou CY, Sheu WH, Lin JY (2011) Weight loss increased serum adiponectin but decreased lipid levels in obese subjects whose body mass index was lower than 30 kg/m^2. *Nutrition Research* 31:378–386

Lee, P. H., Macfarlane, D. J., Lam, T., & Stewart, S. M. (2011). Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *8*(1), 115.

Lee, R. W. W., Sutherland, K., Chan, A. S. L., Zeng, B., Grunstein, R. R., Darendeliler, M. A., … Cistulli, P. A. (2010). Relationship Between Surface Facial Dimensions and Upper Airway Structures in Obstructive Sleep Apnea. *Sleep*, *33*(9), 1249–1254.

Lewis, E. F., Wang, R., Punjabi, N., Gottlieb, D. J., Quan, S. F., Bhatt, D. L., Redline, S. (2017). Impact of continuous positive airway pressure and oxygen on health status in patients with coronary heart disease, cardiovascular risk factors, and obstructive sleep apnea: A Heart Biomarker Evaluation in Apnea Treatment (HEARTBEAT) analysis. *American Heart Journal*, *189*, 59–67.

Lindberg, E., & Gislason, T. (2000). Epidemiology of sleep-related obstructive breathing. *Sleep Medicine Reviews*, *4*(5), 411–433.

Li, K. K., Kushida, C., Powell, N. B., Riley, R. W., & Guilleminault, C. (2000). Obstructive sleep apnea syndrome: a comparison between Far-East Asian and white men. *The Laryngoscope*, *110*(10 Pt 1), 1689–1693.

Li, Y.-L., Xia, X.-H., Zheng, H., Gao, L., Li, Y.-F., Liu, D., Schultz, H. D. (2006). Angiotensin II enhances carotid body chemoreflex control of sympathetic outflow in chronic heart failure rabbits. *Cardiovascular Research*, *71*(1), 129–138.

Li, Y.-L., Gao, L., Zucker, I. H., & Schultz, H. D. (2007). NADPH oxidase-derived superoxide anion mediates angiotensin II-enhanced carotid body chemoreceptor sensitivity in heart failure rabbits. *Cardiovascular Research*, *75*(3), 546–554.

Liu, L., Cao, Q., Guo, Z., & Dai, Q. (2016). Continuous Positive Airway Pressure in Patients With Obstructive Sleep Apnea and Resistant Hypertension: A Meta-Analysis of Randomized Controlled Trials. *Journal of Clinical Hypertension (Greenwich, Conn.)*, *18*(2), 153–158.

Liu, J.-L., Murakami, H., & Zucker, I. H. (1998). Angiotensin II–Nitric Oxide Interaction on Sympathetic Outflow in Conscious Rabbits. *Circulation Research*, *82*(4), 496–502.

Ma, S., Mifflin, S. W., Cunningham, J. T., & Morilak, D. A. (2008). Chronic intermittent hypoxia sensitizes acute hypothalamic-pituitary-adrenal stress reactivity and Fos induction in the rat locus coeruleus in response to subsequent immobilization stress. *Neuroscience*, *154*(4), 1639–1647.

Malhotra, A., Huang, Y., Fogel, R., Lazic, S., Pillar, G., Jakab, M., White, D. P. (2006). Aging influences on pharyngeal anatomy and physiology: the predisposition to pharyngeal collapse. *The American Journal of Medicine*, *119*(1), 72.e9-14.

Marcus, N. J., Li, Y.-L., Bird, C. E., Schultz, H. D., & Morgan, B. J. (2010). CHRONIC INTERMITTENT HYPOXIA AUGMENTS CHEMOREFLEX CONTROL OF SYMPATHETIC ACTIVITY: ROLE OF THE ANGIOTENSIN II TYPE 1 RECEPTOR. *Respiratory Physiology & Neurobiology*, *171*(1), 36–45.

Minemura, H., Akashiba, T., Yamamoto, H., Akahoshi, T., Kosaka, N., & Horie, T. (1998). Acute effects of nasal continuous positive airway pressure on 24-hour blood pressure and catecholamines in patients with obstructive sleep apnea. *Internal Medicine (Tokyo, Japan)*, *37*(12), 1009–1013.

Minoguchi, K., Tazaki, T., Yokoe, T., Minoguchi, H., Watanabe, Y., Yamamoto, M., & Adachi, M. (2004). Elevated production of tumor necrosis factor-alpha by monocytes in patients with obstructive sleep apnea syndrome. *Chest*, *126*(5), 1473–1479.

Mooe, T., Gullsby, S., Rabben, T., & Eriksson, P. (1996). Sleep-disordered breathing: a novel predictor of atrial fibrillation after coronary artery bypass surgery. *Coronary Artery Disease*, *7*(6), 475–478. Retrieved from

Munoz, R., Duran-Cantolla, J., Martínez-Vila, E., Gallego, J., Rubio, R., Aizpuru, F., & De La Torre, G. (2006). Severe sleep apnea and risk of ischemic stroke in the elderly. *Stroke*, *37*(9), 2317–2321.

National Center for Health Statistics. Health, United States, 2016: With Chartbook on Long-term Trends in Health. Hyattsville, MD. 2017

Newman, A. B., Foster, G., Givelber, R., Nieto, F. J., Redline, S., & Young, T. (2005). Progression and regression of sleep-disordered breathing with changes in weight: the Sleep Heart Health Study. *Archives of Internal Medicine*, *165*(20), 2408–2413.

O'Connor, G. T., Lind, B. K., Lee, E. T., Nieto, F. J., Redline, S., Samet, J. M., Sleep Heart Health Study Investigators. (2003). Variation in symptoms of sleep-disordered breathing with race and ethnicity: the Sleep Heart Health Study. *Sleep*, *26*(1), 74–79.

Pallesen, S., Nordhus, I. H., Omvik, S., Sivertsen, B., Tell, G. S., & Bjorvatn, B. (2007). Prevalence and Risk Factors of Subjective Sleepiness in the General Adult Population. *Sleep*, *30*(5), 619–624.

Pascot, A., Lemieux, I., Prud'homme, D., Tremblay, A., Nadeau, A., Couillard, C., … Després, J.-P. (2001). Reduced HDL particle size as an additional feature of the atherogenic dyslipidemia of abdominal obesity. *Journal of Lipid Research*, *42*(12), 2007–2014.

Patel, S. R., White, D. P., Malhotra, A., Stanchina, M. L., & Ayas, N. T. (2003). Continuous positive airway pressure therapy for treating sleepiness in a diverse population with obstructive sleep apnea: results of a meta-analysis. *Archives of Internal Medicine*, *163*(5), 565–571.

Peker, Y., Carlson, J., & Hedner, J. (2006). Increased incidence of coronary artery disease in sleep apnoea: a long-term follow-up. *The European Respiratory Journal*, *28*(3), 596–602.

Peng, Y.-J., Overholt, J. L., Kline, D., Kumar, G. K., & Prabhakar, N. R. (2003). Induction of sensory long-term facilitation in the carotid body by intermittent

hypoxia: Implications for recurrent apneas. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(17), 10073–10078.

Peppard, P. E., Young, T., Barnet, J. H., Palta, M., Hagen, E. W., & Hla, K. M. (2013). Increased prevalence of sleep-disordered breathing in adults. *American Journal of Epidemiology*, *177*(9),

Peppard, P. E., Young, T., Palta, M., & Skatrud, J. (2000). Prospective Study of the Association between Sleep-Disordered Breathing and Hypertension. *New England Journal of Medicine*, *342*(19), 1378–1384.

Punjabi, N. M. (2008). The Epidemiology of Adult Obstructive Sleep Apnea. *Proceedings of the American Thoracic Society*, *5*(2), 136–143.

Punjabi, N. M., & Polotsky, V. Y. (2005). Disorders of glucose metabolism in sleep apnea. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, *99*(5), 1998–2007.

Pereira, M. A., FitzGerald, S. J., Gregg, E. W., Joswiak, M. L., Ryan, W. J., Suminski, R. R.,, Zmuda, J. M. (1997). A Collection of Physical Activity Questionnaires for Health-Related Research.

Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., … Olson, R. D. (2018). The Physical Activity Guidelines for Americans. *JAMA*, *320*(19), 2020–2028.

Poppel, M. N. M. van, Chinapaw, M. J. M., Mokkink, L. B., Mechelen, W. van, & Terwee, C. B. (2010). Physical Activity Questionnaires for Adults. *Sports Medicine*, *40*(7), 565–600.

Punjabi, N. M., Shahar, E., Redline, S., Gottlieb, D. J., Givelber, R., Resnick, H. E., & Sleep Heart Health Study Investigators. (2004). Sleep-disordered breathing, glucose

intolerance, and insulin resistance: the Sleep Heart Health Study. *American Journal of Epidemiology*, *160*(6), 521–530.

Punjabi, N. M., Sorkin, J. D., Katzel, L. I., Goldberg, A. P., Schwartz, A. R., & Smith, P. L. (2002). Sleep-disordered breathing and insulin resistance in middle-aged and overweight men. *American Journal of Respiratory and Critical Care Medicine*, *165*(5), 677–682.

Quan, S. F., O'Connor, G. T., Quan, J. S., Redline, S., Resnick, H. E., Shahar, E., Sherrill, D. L. (2007). Association of physical activity with sleep-disordered breathing. *Sleep and Breathing*, *11*(3), 149–157.

Redline, S., Schluchter, M. D., Larkin, E. K., & Tishler, P. V. (2003). Predictors of Longitudinal Change in Sleep-Disordered Breathing in a Nonclinic Population. *Sleep*, *26*(6), 703–709.

Redline, S., Tishler, P. V., Hans, M. G., Tosteson, T. D., Strohl, K. P., & Spry, K. (1997). Racial differences in sleep-disordered breathing in African-Americans and Caucasians. *American Journal of Respiratory and Critical Care Medicine*, *155*(1), 186–192.

Redline, S., Tishler, P. V., Tosteson, T. D., Williamson, J., Kump, K., Browner, I., Krejci, P. (1995). The familial aggregation of obstructive sleep apnea. *American Journal of Respiratory and Critical Care Medicine*, *151*(3 Pt 1), 682–687.

Redline, S., & Tishler, P. V. (2000). The genetics of sleep apnea. *Sleep Medicine Reviews*, *4*(6), 583–602.

Reiff, G. G., Montoye, H. J., Remington, R. D., Napier, J. A., Metzner, H. L., & Epstein, F. H. (1967). Assessment of physical activity by questionnaire and interview. *The Journal of Sports Medicine and Physical Fitness*, *7*(3), 135–142.

Rejeski, W. J., & Mihalko, S. L. (2001). Physical Activity and Quality of Life in Older Adults. *The Journals of Gerontology: Series A*, *56*, 23–35.

Rotenberg, B. W., Murariu, D., & Pang, K. P. (2016). Trends in CPAP adherence over twenty years of data collection: a flattened curve. *Journal of Otolaryngology - Head & Neck Surgery*, *45*.

Rothney, M. P., Schaefer, E. V., Neumann, M. M., Choi, L., & Chen, K. Y. (2008). Validity of physical activity intensity predictions by ActiGraph, Actical, and RT3 accelerometers. *Obesity (Silver Spring, Md.)*, *16*(8), 1946–1952.

Sahlin, C., Sandberg, O., Gustafson, Y., Bucht, G., Carlberg, B., Stenlund, H., & Franklin, K. A. (2008). Obstructive sleep apnea is a risk factor for death in patients with stroke: a 10-year follow-up. *Archives of Internal Medicine*, *168*(3), 297–301.

Sallis, J. F. (1991). Self-Report Measures of Children's Physical Activity. *Journal of School Health*, *61*(5), 215–219.

Santos-Lozano, A., Santín-Medeiros, F., Cardon, G., Torres-Luque, G., Bailón, R., Bergmeir, C., Garatachea, N. (2013). Actigraph GT3X: Validation and Determination of Physical Activity Intensity Cut Points. *International Journal of Sports Medicine*, *34*(11), 975–982.

Sasaki, J. E., John, D., & Freedson, P. S. (2011). Validation and comparison of ActiGraph activity monitors. *Journal of Science and Medicine in Sport*, *14*(5), 411–416.

Sawyer, A. M., Gooneratne, N. S., Marcus, C. L., Ofer, D., Richards, K. C., & Weaver, T. E. (2011). A systematic review of CPAP adherence across age groups: Clinical and empiric insights for developing CPAP adherence interventions. *Sleep Medicine Reviews*, *15*(6), 343–356.

Seneviratne, U., & Puvanendran, K. (2004). Excessive daytime sleepiness in obstructive sleep apnea: prevalence, severity, and predictors. *Sleep Medicine*, *5*(4), 339–343.

Sengul, Y. S., Ozalevli, S., Oztura, I., Itil, O., & Baklan, B. (2011). The effect of exercise on obstructive sleep apnea: a randomized and controlled trial. *Sleep and Breathing*, *15*(1), 49–56.

Shiota, S., Ryan, C. M., Chiu, K., Ruttanaumpawan, P., Haight, J., Arzt, M., Bradley, T. D. (2007). Alterations in upper airway cross-sectional area in response to lower body positive pressure in healthy subjects. *Thorax*, *62*(10), 868–872. 1a

Simpson, L., McArdle, N., Eastwood, P. R., Ward, K. L., Cooper, M. N., Wilson, A. C., Mukherjee, S. (2015). Physical Inactivity Is Associated with Moderate-Severe Obstructive Sleep Apnea. *Journal of Clinical Sleep Medicine: JCSM: Official Publication of the American Academy of Sleep Medicine*, *11*(10), 1091–1099.

Sin, D. D., Mayers, I., Man, G. C. W., & Pawluk, L. (2002). Long-term compliance rates to continuous positive airway pressure in obstructive sleep apnea: a population-based study. *Chest*, *121*(2), 430–435.

Skevington, S. M., & Wright, A. (2001). Changes in the quality of life of patients receiving antidepressant medication in primary care: Validation of the WHOQOL–100. *The British Journal of Psychiatry*, *178*(3), 261–267.

Skomro, R. P., & Kryger, M. H. (1999). Clinical presentations of obstructive sleep apnea syndrome. *Prog Cardiovasc Dis, 41*(5), 331-340.

Smith, B. J., Marshall, A. L., & Huang, N. (2005). Screening for physical activity in family practice: evaluation of two brief assessment tools. *American Journal of Preventive Medicine*, *29*(4), 256–264.

Sorajja, D., Gami, A. S., Somers, V. K., Behrenbeck, T. R., Garcia-Touchard, A., & Lopez-Jimenez, F. (2008). Independent association between obstructive sleep apnea and subclinical coronary artery disease. *Chest*, *133*(4), 927–933.

Sternfeld, B., Ainsworth, B. E., & Quesenberry, C. P. (1999). Physical activity patterns in a diverse population of women. *Preventive Medicine*, *28*(3), 313–323.

Strohl, K. P., & Redline, S. (1996). Recognition of obstructive sleep apnea. *American Journal of Respiratory and Critical Care Medicine*, *154*(2 Pt 1), 279–289.

Strout, K. A., & Howard, E. P. (2012). The Six Dimensions of Wellness and Cognition in Aging Adults. *Journal of Holistic Nursing*, *30*(3), 195–204.

Strohl, K. P., & Redline, S. (1996). Recognition of obstructive sleep apnea. *American Journal of Respiratory and Critical Care Medicine*, *154*(2 Pt 1), 279–289.

Svanborg, E. (2005). Impact of obstructive apnea syndrome on upper airway respiratory muscles. *Respiratory Physiology & Neurobiology*, *147*(2–3), 263–272.

Sylvia, L. G., Bernstein, E. E., Hubbard, J. L., Keating, L., & Anderson, E. J. (2014). Practical guide to measuring physical activity. *Journal of the Academy of Nutrition and Dietetics*, *114*(2), 199–208.

Tager, I. B., Hollenberg, M., & Satariano, W. A. (1998). Association between self-reported leisure-time physical activity and measures of cardiorespiratory fitness in an elderly population. *American Journal of Epidemiology*, *147*(10), 921–931

Tchernof, A., & Després, J.-P. (2013). Pathophysiology of Human Visceral Obesity: An Update. *Physiological Reviews*, *93*(1), 359–404.

Tchernof A, Lamarche B, Prud'Homme D, Nadeau A, Moorjani S, Labrie F, Després JP (1996). The dense LDL phenotype. Association with plasma lipoprotein levels, visceral obesity, and hyperinsulinemia in men. *Diabetes Care* 19: 629–637

Theorell-Haglöw, J., Berne, C., Janson, C., & Lindberg, E. (2011). The role of obstructive sleep apnea in metabolic syndrome: a population-based study in women. *Sleep Medicine*, *12*(4), 329–334.

Thomas, R. J., Rosen, B. R., Stern, C. E., Weiss, J. W., & Kwong, K. K. (2005). Functional imaging of working memory in obstructive sleep-disordered breathing. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, *98*(6), 2226–2234.

Tishler, P. V., Larkin, E. K., Schluchter, M. D., & Redline, S. (2003). Incidence of sleep-disordered breathing in an urban adult population: the relative importance of risk factors in the development of sleep-disordered breathing. *JAMA*, *289*(17), 2230–2237.

Ueno, L. M., Drager, L. F., Rodrigues, A. C. T., Rondon, M. U. P. B., Braga, A. M. F. W., Mathias, W., Negrão, C. E. (2009). Effects of exercise training in patients with chronic heart failure and sleep apnea. *Sleep*, *32*(5), 637–647.

van Poppel, M. N. M., Chinapaw, M. J. M., Mokkink, L. B., van Mechelen, W., & Terwee, C. B. (2010). Physical activity questionnaires for adults: a systematic

review of measurement properties. *Sports Medicine (Auckland, N.Z.)*, *40*(7), 565–600.

Vandelanotte, C., De Bourdeaudhuij, I., Philippaerts, R., Sjöström, M., & Sallis, J. (2005). Reliability and Validity of a Computerized and Dutch Version of the International Physical Activity Questionnaire (IPAQ). *Journal of Physical Activity and Health*, *2*(1), 63–75.

Veasey, S. C., Davis, C. W., Fenik, P., Zhan, G., Hsu, Y.-J., Pratico, D., & Gow, A. (2004). Long-term intermittent hypoxia in mice: protracted hypersomnolence with oxidative injury to sleep-wake brain regions. *Sleep*, *27*(2), 194–201.

Ware, J. C., McBrayer, R. H., & Scott, J. A. (2000). Influence of sex and age on duration and frequency of sleep apnea events. *Sleep*, *23*(2), 165–170.

Weaver, T. E., & Grunstein, R. R. (2008). Adherence to continuous positive airway pressure therapy: the challenge to effective treatment. *Proceedings of the American Thoracic Society*, *5*(2), 173–178.

Wessendorf, T. E., Teschler, H., Wang, Y. M., Konietzko, N., & Thilmann, A. F. (2000). Sleep-disordered breathing among patients with first-ever stroke. *Journal of Neurology*, *247*(1), 41–47.

West, S. D., Kohler, M., Nicoll, D. J., & Stradling, J. R. (2009). The effect of continuous positive airway pressure treatment on physical activity in patients with obstructive sleep apnoea: A randomised controlled trial. *Sleep Medicine*, *10*(9), 1056–1058.

White, L. H., & Bradley, T. D. (2013). Role of nocturnal rostral fluid shift in the pathogenesis of obstructive and central sleep apnoea. *The Journal of Physiology*, *591*(5), 1179–1193.

Wolkove, N., Baltzan, M., Kamel, H., Dabrusin, R., & Palayew, M. (2008). Long-term compliance with continuous positive airway pressure in patients with obstructive sleep apnea. *Canadian Respiratory Journal : Journal of the Canadian Thoracic Society*, *15*(7), 365–369.

Wozniak, D. R., Lasserson, T. J., & Smith, I. (2014). Educational, supportive and behavioural interventions to improve usage of continuous positive airway pressure machines in adults with obstructive sleep apnoea. *The Cochrane Database of Systematic Reviews*, (1), CD007736.

Young, T., Palta, M., Dempsey, J., Skatrud, J., Weber, S., & Badr, S. (1993). The occurrence of sleep-disordered breathing among middle-aged adults. *The New England Journal of Medicine*, *328*(17), 1230–1235.

Zhao, Y. Y., Wang, R., Gleason, K. J., Lewis, E. F., Quan, S. F., Toth, C. M., (2017). Effect of Continuous Positive Airway Pressure Treatment on Health-Related Quality of Life and Sleepiness in High Cardiovascular Risk Individuals With Sleep Apnea: Best Apnea Interventions for Research (BestAIR) Trial. *Sleep*, *40*(4).

Zhu, Y., Fenik, P., Zhan, G., Mazza, E., Kelz, M., Aston-Jones, G., & Veasey, S. C. (2007). Selective loss of catecholaminergic wake active neurons in a murine sleep apnea model. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *27*(37), 10060–10071.

Zorad, S., Fickova, M., Zelezna, B., Macho, L., & Kral, J. G. (1995). The role of angiotensin II and its receptors in regulation of adipose tissue metabolism and cellularity. *General Physiology and Biophysics*, *14*(5), 383–391.

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Instructor: 2016-present
Health Science Division
Franklin College, Franklin, IN

Graduate Assistant: 2015-2016
Kinesiology and Health Promotion
University of Kentucky, Lexington, KY

Instructor: 2015
General Studies Department
Northeast Wisconsin Technical College, Green Bay, WI

Graduate Assistant: 2013-2015
School of Health and Human Performance
Northern Michigan University, Marquette, MI

Teaching Experience
Franklin College
KIN 210 - Applied Human Physiology
KIN 220 - Applied Human Anatomy
EXE 244 - Strength and Conditioning
EXE 251 - Structural Anatomy/Kinesiology
EXE 372 - Exercise Physiology
WNL 276 - Ireland: Sport, History and Culture (study abroad course)

University of Kentucky
KHP 420 - Physiology of Exercise
KHP 450 - Exercise Testing and Prescription

Northeast Wisconsin Technical College
10806193 - General Anatomy and Physiology

Northern Michigan University
UN100 - Introduction to Sports Science
HP 200 - Physical Well Being
ES 315 - Exercise Physiology
ES 317 - Anatomical Kinesiology

Service Experience
Service to Franklin College
- Assisted with the creation of exercise science program learning outcomes and curriculum
- Lead group of students from all majors across campus to Ireland to study history and sport
- Met with prospective students and their families multiple times each semester to discuss exercise science major
- Attended college showcase days to discuss exercise science program with prospective students
- Assisted with bringing virtual reality to the college library
- Wrote multiple technology grants to bring new equipment (virtual reality and ambulatory blood pressure monitor) to department
- Committee member: College wide advising committee

Poster Presentations
Adolphs MW, SN Drum, BJ Dixon, PB Watts, RL Jensen. The Effects of High Intensity Intermittent Exercise in Normobaric Hypoxia on Aerobic Capacity and Body Composition in Overweight and Obese Sedentary Adults. Midwest Regional Chapter of American College of Sports Medicine, Merrillville, IN, 2014.

Allen BJ, HA Bennett, JN Leachman, MW Adolphs. The Effects of virtual reality Gaming Versus Treadmill Exercise on Perceived Enjoyment and Heart Rate Reserve. Midwest Regional Chapter of American College of Sports Medicine, Grand Rapids, MI, 2017.

Leachman JN, Allen BJ, HA Bennett, MW Adolphs. The Effects of Virtual Reality Gaming on Post Exercise Hypotension. Midwest Regional Chapter of American College of Sports Medicine, Grand Rapids, MI, 2018.

Oral Presentations
Adolphs MW, AS Kaleth. The Validity and Reliability of the PAVS and IPAQ-SF as Physical Activity Assessment Tools in Patients with Obstructive Sleep Apnea. Midwest Regional Chapter of American College of Sports Medicine, Chicago, IL, 2019.

Grant Activity
$1,500 Excellence in Education Grant, Northern Michigan University. The Effects of High Intensity Intermittent Exercise in Normobaric Hypoxia on Aerobic Capacity and Body Composition in Overweight and Obese Sedentary Adults. 2014.

$800 Technology Grant, Franklin College. HTC VIVE Virtual Reality. 2016.

$910 Technology Grant, Franklin College. Welch Allyn Blood Pressure Monitor. 2017.